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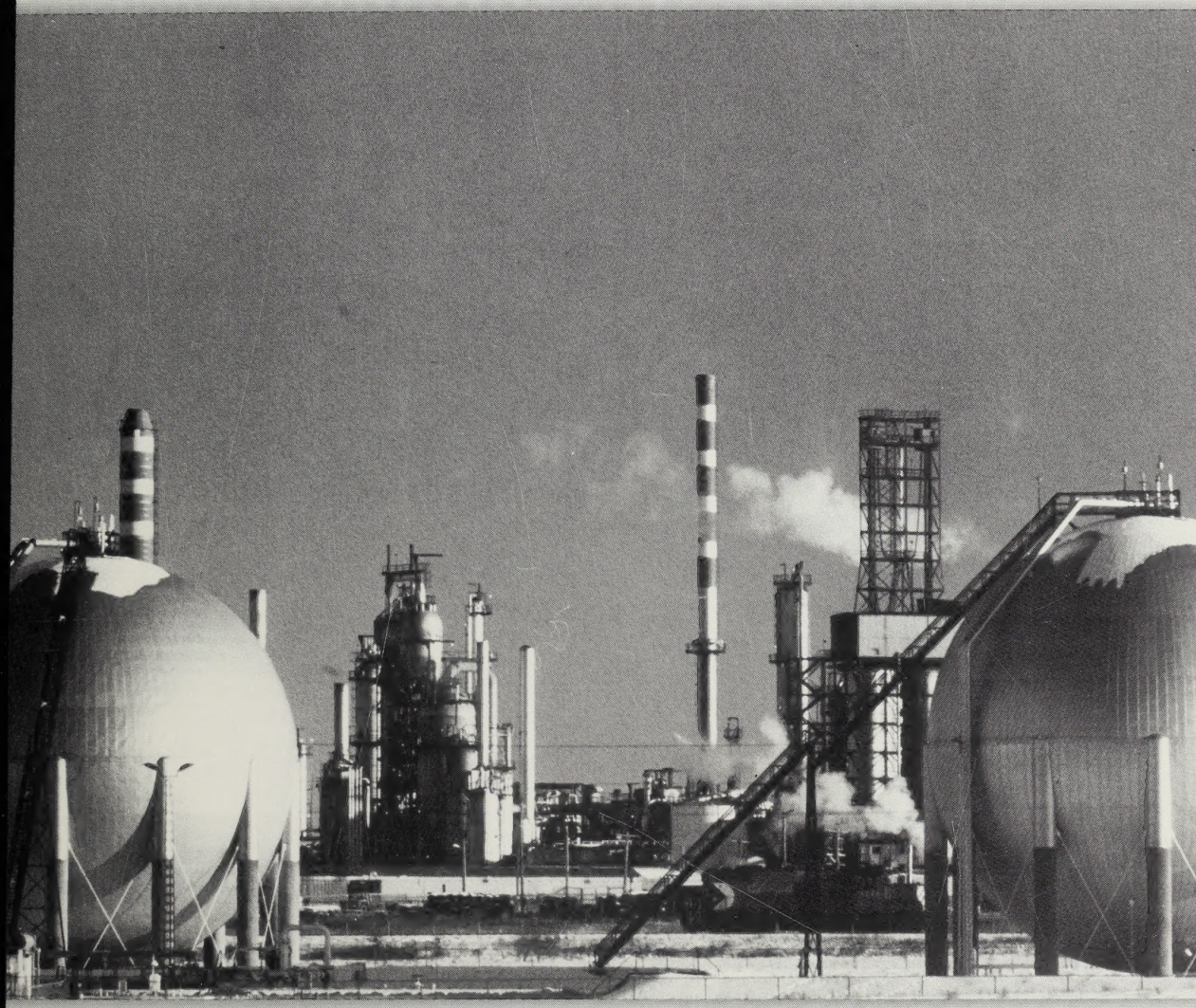

MODULE 6

Applications of Chemistry

Distance Learning

Alberta EDUCATION

SEP 14 1995

Science 20

Module 6

Applications of Chemistry

Alberta EDUCATION

Distance Learning

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Science 20
Student Module
Module 6
Applications of Chemistry
Alberta Distance Learning Centre
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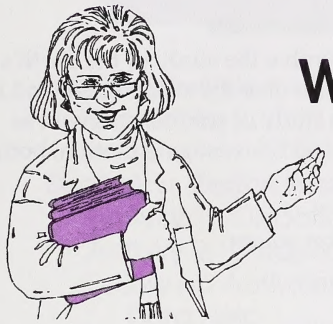
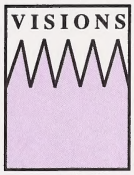


Welcome to Module 6!

We hope you'll enjoy your study of Applications of Chemistry.

To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.

When you see this icon, study the appropriate pages in your textbook.

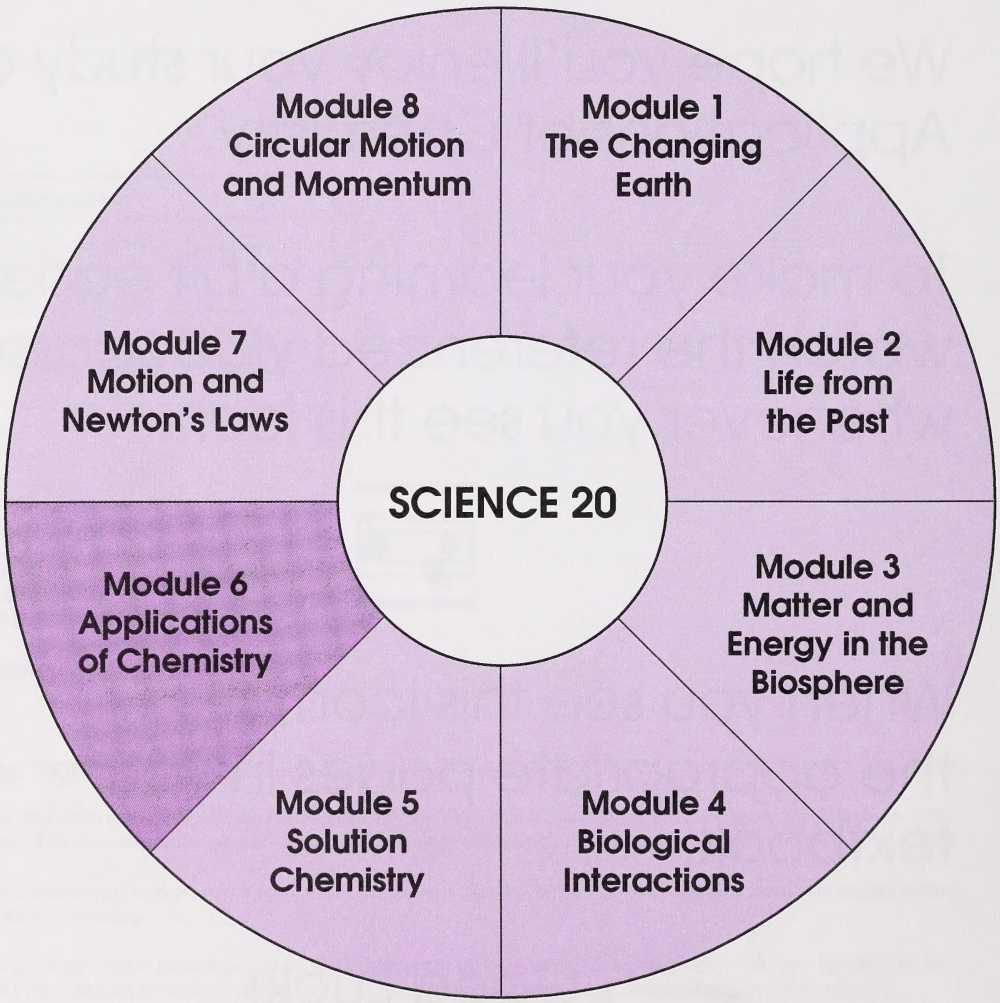


Good Luck!

COURSE OVERVIEW

This course contains eight modules. Modules 1 and 2 involve the study of the Earth's physical features and past life history. Modules 3 and 4 involve the study of life and its interaction with the Earth. Modules 5 and 6 involve the study of solutions as well as how chemistry is used for everyday things. Modules 7 and 8 investigate motion, both on Earth and in space.

The module you are working on is highlighted in a darker colour.



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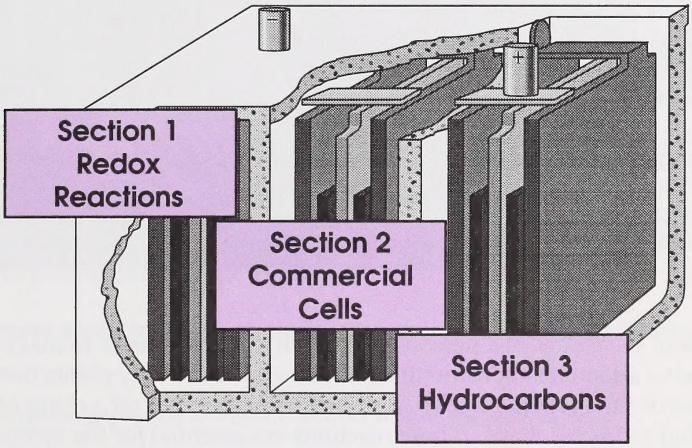
MODULE OVERVIEW

Next time you go for a ride in the family car, take a good look at it. What is it made of? You might be inclined to say metal, but check again. If it is a newer car you may notice that a larger number of the parts, including the wheel wells, front and rear bumper covering, moldings, and trim are made of plastic. Why plastic? How are the plastics used for certain parts of a car made? You turn the ignition and the car starts. What provides the energy to start the car? What provides the energy to keep it running?

Module 6 deals with electrochemistry and organic chemistry – two areas of chemistry which can answer these questions. You will study a special type of chemical reaction called a redox reaction, its relation to corrosion, as well as its industrial application in batteries. You will also examine the characteristics and formation of hydrocarbons and their polymers.

Module 6
Applications of Chemistry



Evaluation

Your mark in this module will be determined by your work in the Assignment Booklet. You must complete all assignments. In this module you are expected to complete three section assignments. The assignment breakdown is as follows:

Section 1 Assignment	**25 marks**
Section 2 Assignment	**35 marks**
Section 3 Assignment	**40 marks**
TOTAL	**100 marks**

Section

1 Redox Reactions

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One of the duties of a person working in a greenhouse is to make sure that the plants receive adequate exposure to light. Do you know why plants need light to grow? Light provides the energy needed in photosynthesis to set off a chain of special reactions called redox reactions. These reactions are essential for the synthesis of materials for plant growth. Your cells cannot trap light energy; thus, you must eat plants or animals to get the fuel necessary for the redox reactions in your body, which are essential for your growth.

In this section you will learn about the nature of oxidation-reduction reactions (redox reactions) and their application to everyday life and technology.

Activity 1: Oxidation and Reduction

redox reaction – a reaction involving transfer of electrons

Whether it is burning wood or igniting gasoline in a car's engine, combustion is one of the most common examples of a **redox reaction**. The chemical reaction that produces rust is also a redox reaction that causes millions of dollars worth of damage every year. Redox reactions also occur in every cell of the human body when glucose (sugar) is oxidized to produce energy for the body.

VISIONS

To learn more about redox reactions in everyday life, read pages 289 and 290 of *Visions 2*.

1. List three examples of a redox reaction from everyday life.

reduction – a chemical change that involves the gain of electrons by an atom or an ion

oxidation – a chemical change that involves the loss of electrons by an atom or an ion

Because all the examples you listed involve the exchange of electrons, chemists have defined them as redox reactions. The word *redox* is an abbreviation for the terms **reduction** and **oxidation**. Pages 293 and 295 of *Visions 2* provide examples of redox reactions. Read these pages to answer question 2.

2. a. Write the simple composition reaction for the formation of sodium chloride.

   b. Write the two reactions with the electrons shown.

Check your answers by turning to the Appendix, Section 1: Activity 1.

half-reactions – the oxidation or reduction reaction parts of redox reactions

The two reactions your textbook provides with electrons shown as a product or a reactant are called **half-reactions**.

The equation for the net reaction can be split into two half-reactions. These two halves can be added to get a whole equation. You will first learn the oxidation half-reaction; then you will learn the reduction half-reaction.

The term *oxidation* was first applied to processes in which oxygen combined with other elements. In the photograph of the rusting truck, oxygen from the air combines with iron in the truck's body to form hydrated iron(III) oxide (rust). When oxygen reacts slowly with iron to form rust (Fe_2O_3) or when carbon burns in oxygen to form carbon dioxide (CO_2), oxidation is occurring. As a result you might think that oxidation is only when an element combines with oxygen. However, oxidation is now defined as a process during which electrons are lost from atoms or ions. Some examples of atoms losing electrons are as follows:

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$$Cu_{(s)} \rightarrow Cu^{2+}{}_{(aq)} + 2e^-$$

$$Na_{(s)} \rightarrow Na^{+}{}_{(aq)} + e^-$$

3. Study the two previous oxidation half-reactions. What generalization can you make about oxidation half-reactions?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The term *reduction* was used to describe reactions in which ores were reduced to extract metal from them. However, metals can be produced by several different methods. Reduction is now defined as a process during which electrons are added to atoms or ions. Some examples of reduction half-reactions are as follows:

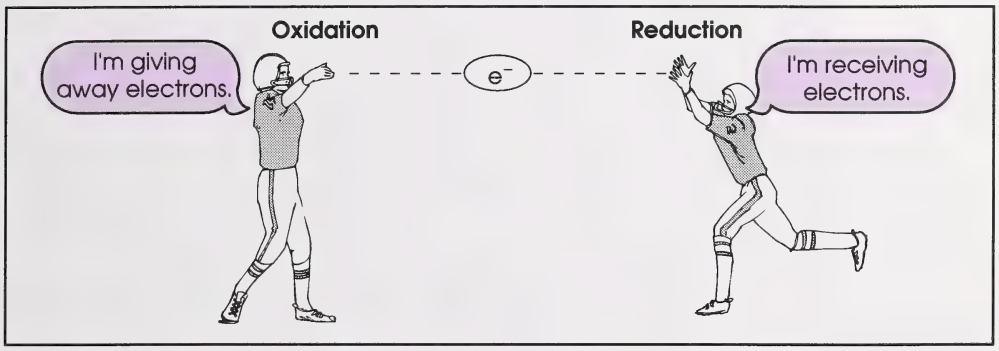
$$Fe^{2+}{}_{(aq)} + 2e^- \rightarrow Fe_{(s)}$$

$$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-{}_{(aq)}$$

4. Study the two previous reduction half-reactions. What generalization can you make about reduction half-reactions?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The following diagram may help you to remember which reaction loses electrons and which one gains electrons. Think of an oxidation reaction as a quarterback and a reduction reaction as a receiver.



VISIONS

Review pages 293 and 295 of your textbook to prepare yourself for writing redox reactions.

5. How are the two half-reactions different from one another?

6. Is it possible to have an oxidation half-reaction or a reduction half-reaction by itself? Explain.

7. Classify each of the following half-reactions as oxidation or reduction.

a. $Mg^{2+}_{(aq)} + 2e^- \rightarrow Mg_{(s)}$

b. $H_{2(g)} \rightarrow 2H^+_{(aq)} + 2e^-$

c. $Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn_{(s)}$

d. $2I^-_{(aq)} \rightarrow I_{2(s)} + 2e^-$

VISIONS

8. Answer questions 1 and 3 on page 296 of your textbook. (For question 3 you will have to write a balanced equation for the reaction between magnesium metal and a solution of silver nitrate first. You will find it helpful to review Module 5, Section 3.)

Check your answers by turning to the Appendix, Section 1: Activity 1.

In previous studies you have learned that all elements (metals and non-metals) are different. In the next few pages you will compare the reactivity of metals to find out how they are different.

Scientists have tested the reactions of metals with substances such as oxygen, water, acids, and solutions of compounds made from metals to arrive at some conclusions about how reactive a metal is relative to other metals. The results of the reactions between five metals and oxygen is given in the following table.

TABLE 6.1 REACTIONS BETWEEN FIVE METALS AND OXYGEN

Metal	Behaviour	Product
sodium	catches fire with little heating	sodium peroxide
magnesium	catches fire easily	magnesium oxide
iron	does not burn, but the hot metal glows	iron oxide
copper	does not burn, but the hot metal becomes coated with a black substance	copper oxide
gold	no reaction, no matter how much heat is applied	no product

activity series – a list of elements showing the relative ability of an element to replace other elements in a reaction

9. List the metals in Table 6.1 in order of decreasing reactivity.

VISIONS

10. Check to see if your answer to question 9 is consistent in terms of order of reactivity with the **activity series** given in Table 8.2 on page 291 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 1.

Investigation: Investigating the Activity Series

VISIONS

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Read through Activity 8.1 on pages 292 and 293 of *Visions 2*. Activity 8.1 involves the reactions of metals and solutions containing metal ions to develop an activity series.

Purpose

Compare the reactivity of several metals by determining how they react with the salt solutions of other metals.

PATHWAYS

If you have access to laboratory facilities, do Part A. If you do not have access to laboratory facilities, do Part B.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part A

Materials

The materials are listed on page 292 of your textbook.

Procedure

Step 1: Read the Planning and Procedure sections of Activity 8.1 carefully.
Step 2: Design a chart for your observations.
Step 3: Perform the investigation by following the Procedure section in Activity 8.1.

Observations

11. Record your observations in your chart.

Analysis and Interpretation

12. Answer questions 1 to 7 in the Analysis and Interpretation section on pages 292 and 293 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 1.

VISIONS

From your results, you can conclude that the free metal must be higher in the activity series table for the reaction to occur. In Table 8.2 on page 291 of *Visions 2*, you can see that zinc is higher than copper and silver; therefore, zinc will react with copper nitrate and silver nitrate.

End of Part A

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part B

Materials

Data results are provided in the Observations section.

Procedure

Step 1: Read the Planning and Procedure sections of Activity 8.1 carefully to help you understand the investigation.

Step 2: Study the data results in the Observations section, and use it to answer the questions in the Analysis and Interpretation section.

Observations

The following observations chart shows the results you would have observed if you had carried out the investigation yourself. Reactions occurred as indicated by the word yes.

	$Zn(NO_3)_{2(aq)}$	$AgNO_{3(aq)}$	$Cu(NO_3)_{2(aq)}$	Water
$Zn_{(s)}$	no	yes	yes	no
$Cu_{(s)}$	no	yes	no	no
$Ag_{(s)}$	no	no	no	no

Analysis and Interpretation

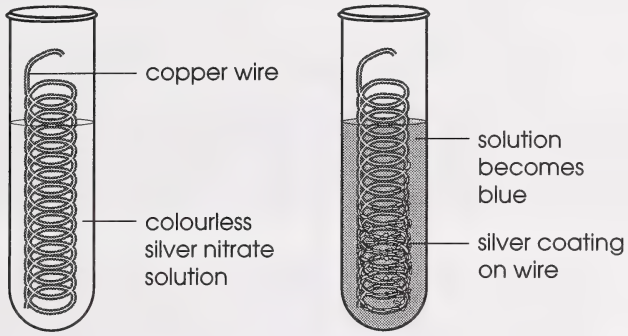
13. Use the results to answer questions 1 to 7 in the Analysis and Interpretation section on pages 292 and 293 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 1.

End of Part B

This investigation has given you the opportunity to understand what an activity series is and how scientists have worked with chemicals to develop it.

14. Look at the following diagram. It shows copper reacting with silver nitrate solution. Which metal is more reactive, silver or copper? Explain how you can tell.

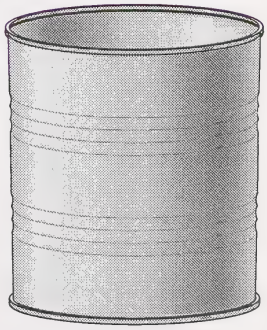


15. Write a rule for the reaction of a metal with solutions of compounds of other metals.

Check your answers by turning to the Appendix, Section 1: Activity 1.

In this activity you have seen how some everyday events are examples of special types of reactions called redox reactions. In the next activity you will discover how these reactions are applied in industry and how these applications benefit human society.

Activity 2: Oxidation and Reduction Technology



Have you ever wondered why steel cans for food are plated with tin? The reason is that tin corrodes to form a protective coating on the surface. This coating protects the surface from further oxidation so no further **corrosion** occurs.

corrosion – the oxidation of metal atoms to metal ions through the loss of electrons

When any metal is attacked by moisture (water), air, or other substances in its surroundings, the metal is said to corrode. Why is it that some metals corrode very easily, others corrode less easily, and some do not corrode at all? The answer lies in the activity series you studied in the previous activity. In general the more reactive a metal is, the more easily it corrodes. Metals toward the top of Table 8.2 on page 291 of your textbook become oxidized more easily compared to those toward the bottom.

VISIONS

VISIONS

Many corrosion processes, including rusting, are **electrochemical** in nature. These processes convert metals into their salts or oxides. Read page 302 in your textbook; then answer questions 1 to 3.

electrochemical – a chemical reaction in which electrons are exchanged in the reactants

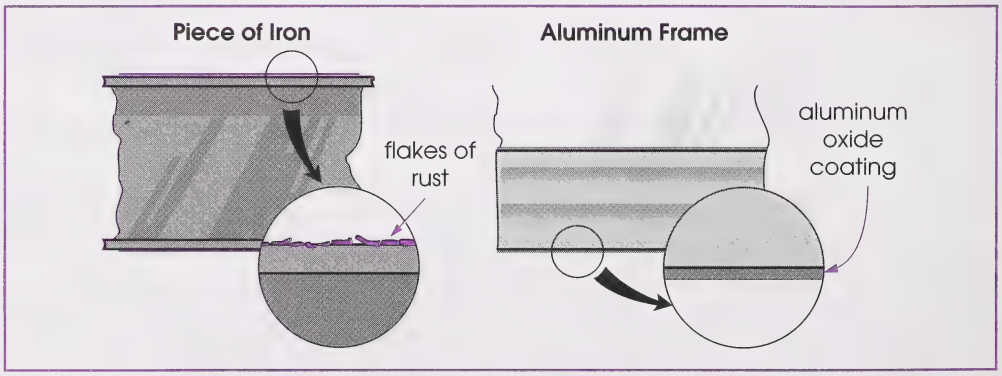
1. Write the simple composition equation for the oxidation of iron to form iron(III) oxide.
2. Which substance is oxidized and which is reduced when iron rusts?
3. What part do water and other chemicals such as salt play in the rusting process?

Check your answers by turning to the Appendix, Section 1: Activity 2.

Another example of corrosion is the oxidation of aluminum. Recall the photograph of the greenhouse at the beginning of Activity 1. It is made from aluminum. Aluminum is used for making airplanes, cooking utensils, greenhouse frames, window frames, and so on.

VISIONS

From the activity series given in Table 8.2 on page 291 of your textbook, you would predict that aluminum is more reactive than iron. Therefore, you may expect aluminum to corrode faster than iron. In fact it does as long as it is clean. However, the reaction stops quickly. The following diagram explains why.



When iron corrodes, rust forms in tiny flakes. Damp air can react past the flakes and still attack the metal. Over a period of time, it rusts all the way through. But when aluminum reacts with air, a coating of its oxide forms and seals the metal underneath. This protects it from further oxidation.

4. If you have ever handled aluminum windows that have been outside, you would find that your fingers get black. Explain why your fingers get black when you handle aluminum windows.

5. How do you think the iron could be made more corrosion resistant?

Check your answers by turning to the Appendix, Section 1: Activity 2.

For further understanding of the process of corrosion, do the following investigation.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Investigation: Studying Corrosion and Its Prevention

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Read through Activity 8.2 on pages 300 to 302 of your textbook.

VISIONS

Part A

Purpose

Examine the rusting of iron under various conditions.

Materials

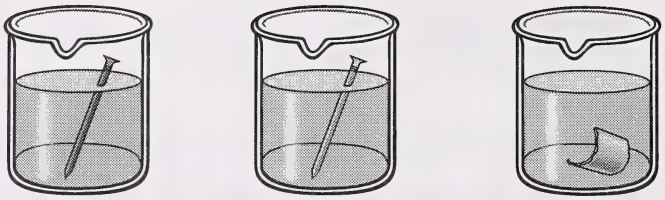
The materials are listed on page 300 of your textbook. Use the 100 mL beakers in place of the 250 mL beakers listed. You can use pickle jars or any jar that has a thin rubber seal inside the lid in place of mason jars.

Procedure

Step 1: Read the Planning section on page 300 carefully. Pay special attention to the safety section.

Step 2: Collect the materials needed and completely read the Procedure section for Part A before starting.

Step 3: Set up three beakers with tap water as shown. The cans used for the metal pieces must be cans that have been tinned. Some cans used today are made of aluminum coated with laquer or vinyl.

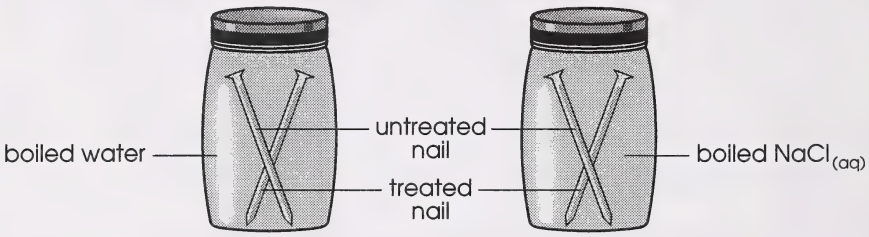


Water and an Untreated Nail | Water and a Galvanized Nail | Water and a Piece of Metal Can

Step 4: Set up three beakers in the same way, using $NaCl_{(aq)}$ instead of water. You will need 500 mL of 0.7 mol/L sodium chloride for the beakers. Prepare an additional amount for the mason jar depending on the size of your jar.

Caution

Step 5: Set up two mason jars as shown. Use tongs, pot holders, or towels to handle the hot jars. You may find it difficult to bring the water in the jars to a boil. You should get acceptable results if the water was close to boiling.



Step 6: Make a chart for your observations.

Step 7: Perform Part A of the investigation as outlined in your textbook.

Observations

6. Record your observations in your chart.

Analysis and Interpretation

VISIONS

7. Answer questions 1 to 6 in the Analysis and Interpretation section on page 301 of *Visions* 2.

Check your answers by turning to the Appendix, Section 1: Activity 2.

End of Part A

Part B

Purpose

Test the effectiveness of some methods used to prevent corrosion.

Materials

The materials are listed on page 301 of your textbook. If you have a lab kit from ADLC, your kit will have a lead strip instead of a silver strip.

Procedure

Step 1: Read the Procedure section on pages 301 and 302 of your textbook. Make a chart for your observations.

Step 2: Perform the investigation as indicated in the Procedure section on pages 301 and 302 of your textbook. If you have an ADLC lab kit, you will need to connect the wires to the alligator clips. Substitute the lead strip for the silver strip.

Observations

8. Record your observations in your chart.

Analysis and Interpretation

9. Answer questions 1 to 3 in the Analysis and Interpretation section on page 302 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 2.

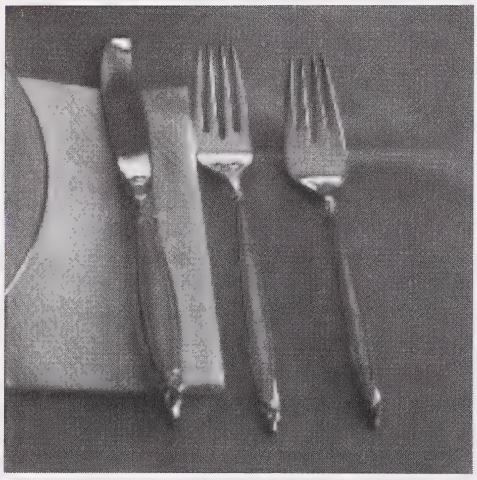
End of Part B

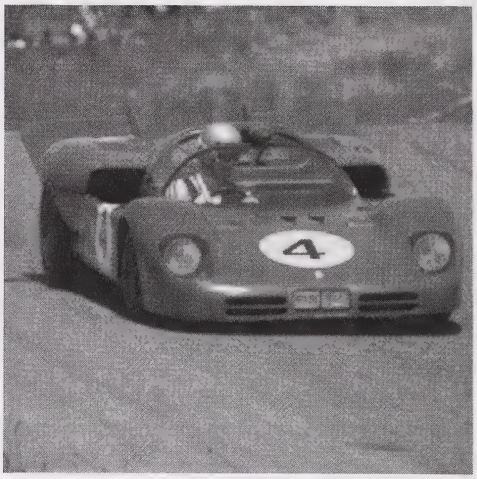
Now that you have learned about corrosion and how it occurs, you will look at some methods used to prevent it, since millions of dollars worth of damage is caused by these chemical reactions every year.

Some methods to prevent corrosion are as follows:

- coating with paint or grease
- galvanization
- plating
- sacrificial protection

The following photographs illustrate two methods of reducing corrosion.





coating – the process of covering a surface with paint, plastic, grease, and so on

galvanization – the process by which iron is given a protective coating of zinc

electroplating – a process of coating a surface with a metal using an electric current

sacrificial protection – a process of protecting one metal from corrosion by coating or connecting to a metal that is higher on the activity series

An example of **coating** may be found at large construction sites which use painted railings and metal frames. Paints that contain lead and zinc are usually used.

An example of **galvanization** can be found on a garbage can made of galvanized iron.

An example of **electroplating** can be found on steel food cans plated with tin. Silverware is also made of a base metal electroplated with silver.

An example of **sacrificial protection** may be found on ships that have attached pieces of magnesium metal to protect them from corrosion. The fact that magnesium is oxidized more easily than iron prevents the corrosion of iron.

PATHWAYS

If you have access to the video entitled *Electrochemistry: Corrosion*, TV Ontario, do Part A. Otherwise, do Part B.

Part A

Obtain the video and go to the part entitled Corrosion. Before viewing the video, review questions 10 to 15 in Part B. Answer these questions as you watch the video.

Part B

To learn more about the various methods of preventing corrosion, read pages 302 to 304 of *Visions 2*; then answer the following questions.

10. Why does rust develop quickly?

11. What name is given to the process by which rust forms?

12. List three methods used to prevent corrosion.

13. What is *cathodic protection*?

14. Why is cathodic protection sometimes called sacrificial protection?

15. Why can zinc and magnesium be used to offer sacrificial or cathodic protection for iron?

Check your answers by turning to the Appendix, Section 1: Activity 2.

End of Part A and Part B

16. Explain the difference between coating, galvanization, and sacrificial protection.

17. To check your understanding of the concepts introduced in this section, answer questions 1 to 7 on page 305 of *Visions 2*.

Check your answers by turning to the Appendix, Section 1: Activity 2.

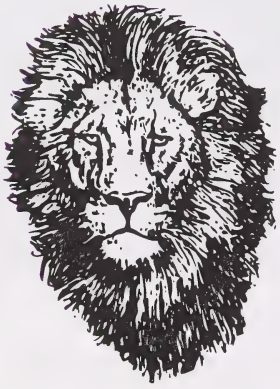
Corrosion occurs when any metal is oxidized. Some metals are oxidized very slowly or not at all. Iron, one of the most common metals used, is affected the most by corrosion. Understanding the nature of redox reactions has enabled the development of technologies to reduce the amount of corrosion that occurs with iron. By minimizing the contact of iron with air, moisture, and salt, humans can save money, time, and energy.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Two ways to remember the oxidation and reduction definitions are as follows:



LEO says **GER**
Loss of **E**lectrons is **O**xidation
Gain of **E**lectrons is **R**eduction

OR

OIL RIG
Oxidation **I**s **L**oss of electrons
Reduction **I**s **G**ain of electrons

1. Write the half-reaction equations for the following changes. State in each case whether the process is oxidation or reduction.

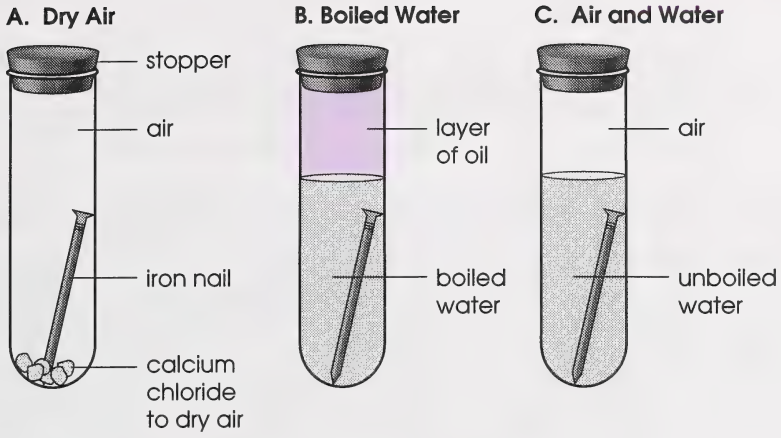
   a. $Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)}$

   b. $Cu^{2+}_{(aq)} \rightarrow Cu_{(s)}$

   c. $H_{2(g)} \rightarrow 2H^{+}_{(aq)}$

   d. $2Cl^{-}_{(aq)} \rightarrow Cl_{2(g)}$

The rusting of iron and steel is an example of corrosion. Study the following diagram to answer questions 2 to 4.



2. In which test tube will the nail rust? Why?

3. What conclusion can you make from the information in the diagram?

4. In the investigation on corrosion, you found that salt increases the amount of corrosion. What additional factor leads to extensive corrosion?

5. Make and complete a chart like the one that follows.

Method of Corrosion Prevention	Technique
coating	
galvanization	
electroplating	
cathodic protection (sacrificial protection)	

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Understanding the nature of redox reactions has enabled the development of various technologies to prevent corrosion as well as to enhance some of the products humans use. Answer any two of the following three questions.

1. Investigate how a process called anodizing is used in industry to prevent corrosion of aluminum. Give two uses for anodized aluminum.

2. Investigate the difference between electroplating and cladding. Give one example where each is used. Compare their advantages and disadvantages.

3. Coins in some countries are made from stainless steel. What is stainless steel? Explain why stainless steel is used for coins.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

This section has focused on the process involved in the corrosion of metals and how knowledge of electrochemistry has helped industry to prevent this oxidation of metals. In the next section you will study electrochemical cells which are essential for television remote controls, car batteries, personal stereo batteries, and so on.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

Section

2 Commercial Cells

The reactions which cause battery-operated devices, such as the ones in the photograph, to work are oxidation-reduction reactions. When electrons are given a path through which to flow, an electric current is established. Spontaneous redox reactions are often used to produce electricity which can do useful work. Electric current can also be used to force a non-spontaneous redox reaction to occur. This process is often used in the extraction of metals from their ores. In either case the place where the reaction occurs is called a cell.

In Section 1 you learned about oxidation and reduction half-reactions. In this section you will see how these reactions can be used either as chemical energy or electrical energy to do useful work. You will learn about both electrochemical and electrolytic cells and their industrial applications.

Activity 1: The Galvanic Cell

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electrochemical cell – a system made from electrodes and electrolytes in which a spontaneous redox reaction produces an electric current; also called a galvanic cell or a voltaic cell

What do the objects in the preceding photographs have in common? Both of these objects need a battery to work. Batteries have become a part of everyday life. People use different types of batteries every day. What most people refer to as a battery, chemists call an **electrochemical cell.** It may also be called a galvanic cell or a voltaic cell.

How do you think the batteries work in the objects shown? Even though the reagents in these cells are different, the basic principle of their function is the same. The reaction which causes each of these to work is a redox reaction. When electrons flow from the substance being oxidized to the substance being reduced, an electric current can be produced. This current can be used to drive an electric motor, which is what happens in a toy car. Electrical energy is changed to mechanical energy.

VISIONS

To learn more about electrochemical cells, read the first two paragraphs of Electricity Is the Movement of Electrons and Ions on page 306 of your textbook; then answer questions 1 to 3.

1. Define the term *electrochemical reaction.*

2. Which type of redox reaction can be used to produce an electric current?

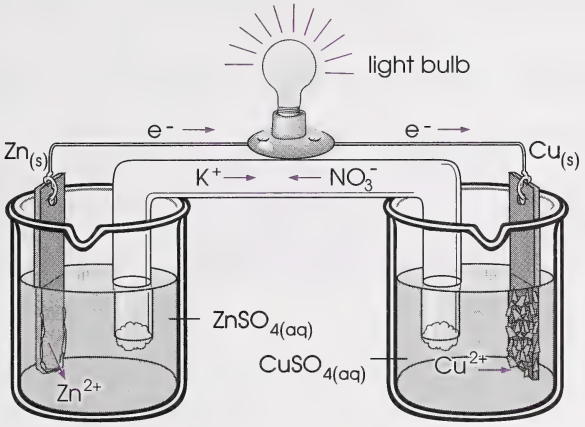
3. Complete the following statements by providing the missing words.

   a. The substance being oxidized _____ electrons, while the substance being reduced _____ electrons.

   b. Electricity can be defined as _____.

Check your answers by turning to the Appendix, Section 2: Activity 1.

In the previous section you discovered that oxidation-reduction reactions involve the transfer of electrons between the reactants and that the redox reaction involves two half-reactions – an oxidation half-reaction and a reduction half-reaction. A spontaneous redox reaction is used to build an electrochemical cell. The following diagram shows a simple galvanic cell prepared in a laboratory.



This electrochemical cell is a copper-zinc cell. Each beaker represents one half-cell in which either the reduction or the oxidation half-reaction will take place. Each half-cell has the following components:

electrode – a solid conductor used in an electrochemical cell to make electrical contact

- an electrolyte
- an **electrode**, usually a solid conductor which does not react with the electrolyte
- a salt bridge with one end immersed in each electrolyte solution

VISIONS

For more information on the galvanic cell, start at the last paragraph on page 306 of your textbook and read up to the start of Activity 8.3 on page 307. Make sure you read the information given in the margins. Now answer the questions that follow.

4. What are two other names for an electrochemical cell?

5. What are the contents of each half-cell?

6. What is a salt bridge and why is it essential for the cell to function?

7. Define the terms *cathode* and *anode*.

8. What information is essential for building a galvanic cell and how do you obtain this information?

Check your answers by turning to the Appendix, Section 2: Activity 1.

To further explore the electrochemical cell, do the following investigation.

Investigation: Building a Galvanic Cell

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Read through Activity 8.3 on pages 307 and 308 of your textbook.

PATHWAYS

If you have access to laboratory facilities, do Part A. If you do not have access to laboratory facilities, do Part B.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part A

Purpose

Build a galvanic cell and measure the electrical energy it produces.

Background Information

- You can build a salt bridge using a U-tube, glass wool, cotton batton, or paper towel to plug the ends.

- Use an electrolyte like sodium nitrate $\left(NaNO_{3(aq)}\right)$ or potassium nitrate $\left(KNO_{3(aq)}\right)$. Sodium nitrate and potassium nitrate are toxic and caustic to the skin. If you spill any on your skin, wash the affected area immediately with cool water.
- You can also use a porous cup instead of the salt bridge and beakers. A porous cup is a ceramic cup which allows ions to flow through the walls but does not allow free mixing of the solutions.

Materials

The materials are listed on page 308 of your textbook.

Procedure

- Read the Planning section on page 307 of your textbook carefully.
- Collect all the materials; then read the Procedure section on page 308 of your textbook before you start the activity.
- Make a chart to record the voltage you measure and any observations you make.
- Follow the Procedure section in your textbook to carry out the investigation.

Observations

9. Record your observations in your chart

Analysis and Interpretation

10. When you complete the investigation, answer questions 1 to 8 in the Analysis and Interpretation section on page 308 of *Visions* 2.

Check your answers by turning to the Appendix, Section 2: Activity 1.

End of Part A

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part B

Purpose

Understand how a galvanic cell can be constructed by viewing a video and analysing what amount of electric current can be produced by a galvanic cell.

Materials

- *Visions* 2
- TV Ontario video entitled *Electrochemistry: Electrochemical Cells*, ACCESS Network, available from the Learning Resources Distributing Centre.
- data results in the Observations section

Procedure

- Read through the Planning and Procedure sections on pages 307 and 308 of your textbook. Also refer to Figure 8.4 on page 307 to help you understand how a galvanic cell is built.
- Watch the TV Ontario video and answer questions 11 to 16 in the Analysis and Interpretation section.
- Use the information in the video and the sample observations provided in the Observations section to answer question 17 in the Analysis and Interpretation section.

Observations

Cell	Voltage (V)	Colour/Mass Changes
Cu-Zn	1.10	Blue colour decreases in intensity. Zinc loses mass and copper is deposited on the copper electrode.
Cu-Mg	2.71	Blue colour decreases in intensity. Magnesium loses mass and copper is deposited at the copper electrode.
Zn-Mg	1.61	Magnesium loses mass and zinc is deposited at the zinc electrode.

Analysis and Interpretation

11. When a lump of zinc metal was put into a beaker with copper sulphate, a brown deposit formed on the copper. What is the brown deposit?
12. Why did the blue colour of the copper sulphate solution become lighter?
13. How can an activity series be used to help construct an electrochemical cell?
14. What is the purpose of having separate beakers?
15. State the purpose of the salt bridge.
16. What happens to each electrode?

17. Answer questions 1 to 7 in the Analysis and Interpretation section on page 308 of your textbook.

Check your answers by turning to the Appendix, Section 2: Activity 1.

End of Part B

The following photograph shows various batteries that are used to operate various items that people use every day.

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Do you know the difference between the batteries shown in the preceding photograph? The battery on the left is a car battery. Since it contains an acid, it is called an acid battery. The batteries in the centre contain a base and are called alkaline batteries. You use alkaline batteries in flashlights, tape recorders, portable stereos, and so on. The batteries on the right contain various metals such as nickel and cadmium and are rechargeable. These batteries might be used in cameras, watches, and various other items where you do not want to change batteries often. Batteries come in different sizes and shapes. The type of battery used depends on its function.

VISIONS

To learn more about various types of batteries and their uses, read pages 309 to 312 of your textbook; then answer the questions that follow.

18. What is the difference between a primary battery and a secondary battery?

19. What types of elements are used for electrodes in lightweight batteries?

20. What is one of the major causes of car battery (acid battery) failure?

21. For further understanding, answer questions 1 to 4 in the Checkpoint section on page 312 of *Visions 2*.

Check your answers by turning to the Appendix, Section 2: Activity 1.

In this activity you have studied electrochemical cells, and you have discovered how the batteries in a toy work. In the next activity you will discover some industrial applications of redox reactions.

Activity 2: The Electrolytic Cell

Do you drive a car? Have you tried to start a car on a cold, winter morning and found the battery would not turn the motor over? This situation is a familiar one, especially in the cold climate of Canada. A car battery is normally a galvanic cell. However, when a car battery is being recharged or boosted, electrical energy is being applied to a redox reaction in a direction opposite to what it does normally. The battery would be called an electrolytic cell when it is recharging.

In the previous activity you learned that a car battery contains an acid. The following reaction occurs in the car battery when it is being used.

$$Pb_{(s)} + PbO_{2(s)} + 2H_2SO_{4(aq)} \rightarrow 2PbSO_{4(s)} + 2H_2O_{(l)}$$

electrolysis – a process that produces a chemical change by using an electric current

electrolytic cell – a cell in which non-spontaneous chemical changes occur through the application of an electric current

However, when the battery is being recharged, the reverse reaction takes place.

$$2PbSO_{4(s)} + 2H_2O_{(l)} \rightarrow Pb_{(s)} + PbO_{2(s)} + 2H_2SO_{4(aq)}$$

Because the reverse reaction is a non-spontaneous reaction, electrical energy must be put into the system. You can therefore conclude that chemical reactions can be used to produce electrical energy, but electrical energy can be used to produce chemical changes as well.

This process of applying a direct current to force a non-spontaneous reaction to occur is called **electrolysis**. The place (cell) where this reaction occurs is called an **electrolytic cell**.

1. How does an electrolytic cell differ from a galvanic cell?

Check your answers by turning to the Appendix, Section 2: Activity 2.

To learn more about electrolytic cells, complete one of the following pathways.

PATHWAYS

If you have access to laboratory facilities, do Part A. If you do not have access to laboratory facilities, do Part B.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part A

Investigation: Building an Electrolytic Cell

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

Construct an electrolytic cell and observe how it works and how it differs from a galvanic cell.

Background Information

Note the following safety precautions:

Caution

- Wear safety glasses.
- Potassium iodide solution is toxic and stains. If you spill the solution on your skin, immediately wash your skin with cool water.
- After the completion of the lab, dispose of the waste chemicals as directed by your learning facilitator.
- Wash your hands when you finish the investigation.
- Use caution when handling the power source. Be sure not to touch the power source with wet hands.

Materials

- U-tube
- 2 insulated copper wires with alligator clips at both ends
- 2 carbon rods
- power source (use a power pack)
- 50 mL of 1.0 mol/L potassium iodide solution, $KI_{(aq)}$
- stand with a clamp
- eyedropper
- watch glass
- litmus paper

Procedure

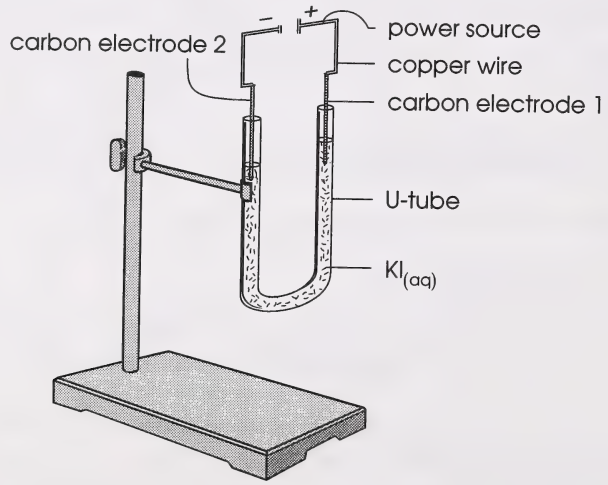
Follow the next four steps and set up the apparatus as shown in the diagram.

Step 1: Clamp the U-tube to the stand.

Step 2: Pour the potassium iodide solution into the U-tube.

Step 3: Connect one end of each copper wire to the power supply and the other end to the carbon rods.

Step 4: Place the carbon rods in the U-tube as shown in the diagram.



Step 5: Make a chart like the one in the Observations section.

Step 6: Turn on the power supply. Wait for two minutes and observe the changes taking place at the two electrodes.

Step 7: Use the eyedropper to remove some solution from near each electrode, place on a watch glass and test the solution with red and blue litmus paper.

Observations

2. Record your observations in your chart.

	Colour Change	Litmus Test
Electrode 1		
Electrode 2		

Analysis and Interpretation

3. Account for the colour change in the potassium iodide solution at Electrode 1. Write the half-reaction to explain this change. Is this electrode the anode or the cathode?

4. Account for the changes that occured at Electrode 2. Is this electrode the anode or the cathode?

5. Predict what reaction would occur at the cathode if copper(II) sulphate were used instead of potassium iodide solution. What would you observe at this electrode?

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part A

Part B

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Watch the TV Ontario video entitled *Electrochemistry: Electroplating* to learn how an electrolytic cell is constructed and how it works. This video is available through the Learning Resource Distributing Centre. Answer the questions that follow as you watch this segment of the video.

6. What is the reverse of a battery reaction called?

7. In the electrolytic cell the electrode connected to the negative end of the battery or power source acts as the _____, and the electrode connected to the positive end acts as the _____.

8. What will you observe at the two electrodes in this cell when $CuSO_{4(aq)}$ is the electrolyte?

9. What is the direction of the charge flow?

10. State the type of reaction that occurs at the negative (–) electrode? Write the half-reaction.

11. Give the type of reaction that occurs at the positive (+) electrode?

12. What gas is bubbling from the anode?

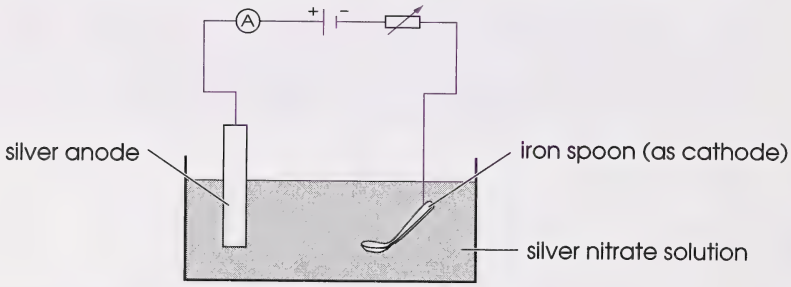
13. Why do you need a power supply for this cell?

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part B

You have now learned what an electrolytic cell is and how it works. Electrolytic cells are used to produce a variety of metals and gases in many industrial applications. Two applications of this cell are electroplating and extraction of metals.

Electroplating



VISIONS

The preceding diagram shows the setup for electroplating silver on a spoon. The object to be plated is always attached to the negative end of the power source which acts as the cathode. When a current is passed, the plating metal deposits at the cathode. Read pages 315 and 316 of your textbook; then answer the following questions.

14. Give two purposes for electroplating.

15. Which metals are used frequently for electroplating?

16. Name three electroplated items with which you are familiar.

17. How is it possible to electroplate ABS plastic?

18. Which substance makes the anode in the electrolytic cell?

19. Chromium was once used for plating various parts of cars including the bumpers, door handles, mirrors, wheel rims, and so on. Check some cars that have been built in the late 1980s or 1990s. Are these parts chrome? What reasons can you give for not using chromium?

20. Briefly describe how "loonies" are made.

Check your answers by turning to the Appendix, Section 2: Activity 2.

Extraction of Metals

Electrolysis is used widely in extraction of metals from their ores. This field of study is called metallurgy. Canada has several extraction plants because energy is cheap compared to other countries.

VISIONS

To learn more about electrolysis, read from the last paragraph on page 316 to page 318 of your textbook; then answer the following questions.

21. A quantity of copper ore has iron, gold, zinc, lead, and platinum impurities. Describe what would happen to each of these impurities during the electrolysis of the copper ore.

22. Why is a metal specified to 99% or 99.9% purity?

23. Which two metals are produced by an electrolytic reaction of their molten salts?

24. a. Canada produced 1.9 million tonnes of primary aluminum in 1992. If 8×10^5 KJ of electricity is required to produce 10 kg of aluminum, how many kilojoules (KJ) of electricity did Canada use to produce this amount of aluminum? (Note: One metric tonne equals 1000 kg.)

    b. If Canada produced approximately 1.8×10^{15} KJ of electricity in 1992, what percent of Canada's total electricity production was used to produce primary aluminum.

25. To check your understanding of electrolytic cells and their applications, do questions 1, 3, and 4 on page 318 of *Visions* 2.

Check your answers by turning to the Appendix, Section 2: Activity 2.

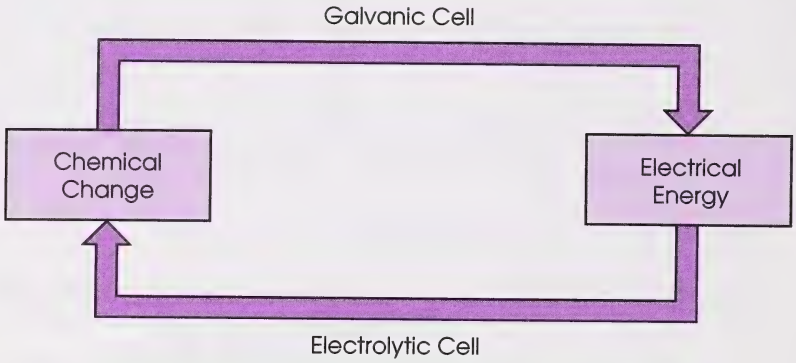
In this activity you have learned how an electrolytic cell works. You studied some applications of electrolytic cells and learned that electrolytic cells require electrical energy to drive the oxidation and reduction reactions.

Follow-up Activities

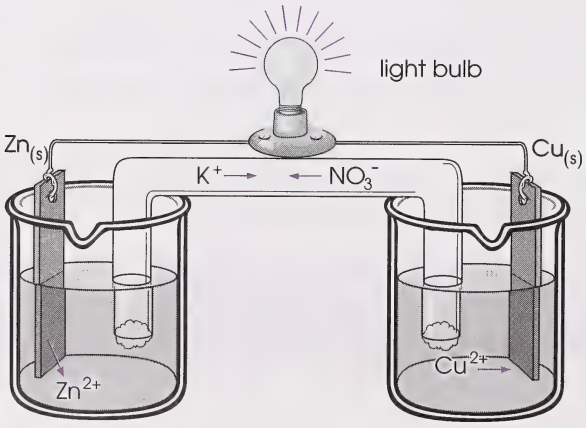
If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

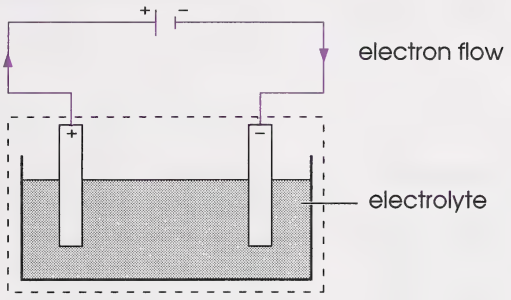
In a galvanic cell, electrical energy is produced as a result of chemical changes in matter. In an electrolytic cell, electrical energy is used to drive a reaction in the reverse direction than it would occur in a galvanic cell. The following diagram illustrates the relation between a galvanic cell and an electrolytic cell.



1. Sketch the following diagram and label the anode, cathode, salt bridge, and the direction of the electron flow. Indicate if this is an electrochemical cell or an electrolytic cell.



2. Label the cathode and the anode in the following diagram. Which type of cell does the diagram represent? How do you know?



3. The following chart compares some properties of a galvanic cell and an electrolytic cell. Make and complete the following chart.

	Galvanic Cell	Electrolytic Cell
Type of Reaction		
Energy Changes		
Anode Reaction		
Cathode Reaction		
Electron Flow		

4. Give one application for a galvanic cell and one for an electrolytic cell.

A good way to remember what happens at each electrode and which electrode is the anode and which is the cathode is to learn the acronyms LEONA and GERPC. These acronyms can be used to represent the following occurrences at each electrode in a cell.

Lose	**G**ain
Electrons	**E**lectrons
Oxidized	**R**educed
Negative	**P**ositive
Anode	**C**athode

This should help you remember that the metal losing the electrons is oxidized and is the anode.

5. The equations for the two half-reactions taking place in a galvanic cell are as follows

$$Cr_{(s)} \rightarrow Cr^{2+}{}_{(aq)} + 2e^- \text{ and } Pb^{2+}{}_{(aq)} + 2e^- \rightarrow Pb_{(s)}$$

   a. Which reaction will occur at the cathode and which will occur at the anode?

   b. In which reaction is the metal oxidized and in which is the metal reduced?

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

Do any two of the following questions. You will need to go to the library and research some of these topics.

1. Describe the process of electrorefining and how it is used. Illustrate with a particular ore and draw a diagram to show the process.

2. The concentration of the reacting species determines the voltage produced by an electrochemical cell. How is the voltage dependent upon the concentration of the reactants?

3. What does the term *half-cell overpotential* mean? List four factors which determine the overpotential required for a cell.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

In this section you have seen how electrochemical reactions can be used commercially and industrially to the advantage of society. You have discovered various applications of electrolytic and electrochemical cells. Redox reactions are the heart of electrochemical and electrolytic cells. Now that you have gained an understanding of redox reactions and have studied the application of these reactions, you can see that society would be much different without the benefits redox reactions provide.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

Section

3 Hydrocarbons

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Did you know that although you are over 50% water, you are also about 25% carbon? All living systems contain the element carbon. In the preceding pictures, the body of the insect contains about 35% carbon, the grass contains about 5% carbon, and the baby contains approximately 25% carbon. Because compounds containing carbon are so varied and numerous, the study of compounds containing carbon is a special branch of chemistry called organic chemistry. Organic compounds actually make up over 95% of all known compounds. Most of these organic compounds are produced synthetically.

In this section you will study the nature of the element carbon and what makes it so special. Then you will discover different types of hydrocarbons formed when carbon reacts with hydrogen. The most familiar hydrocarbon is oil. You will also study polymers, which are formed from repeating units of a basic hydrocarbon.

Activity 1: General Characteristics of Hydrocarbons

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organic compounds – compounds which contain carbon

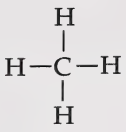
Do you recall from Module 2 what one of Alberta's most important sources of fuel is? Oil! Oil is a fossil fuel – the remains of living things (plants and animals) that lived millions of years ago. Oil, coal, and natural gas are natural sources of **organic compounds**

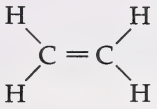
VISIONS

Read the introduction on pages 324 and 325 of *Visions* 2; then answer the following questions.

1. What is a hydrocarbon?
2. List three primary sources of hydrocarbons.
3. Why are the sources of hydrocarbons and organic compounds the same?
4. Explain the term *fossil fuel*. Give two examples.

5. Which of the following are hydrocarbons? Why?

A.


C.


B. $O=C=O$

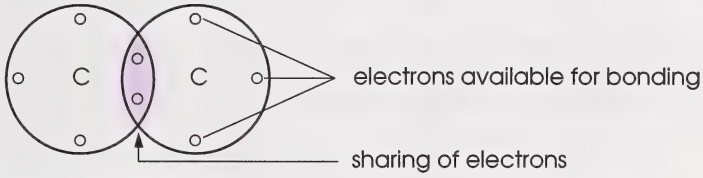
D.

Check your answers by turning to the Appendix, Section 3: Activity 1.

Plants and animals are the living systems which synthesize carbon-containing molecules such as proteins, carbohydrates, fats, vitamins, and so on. Carbon is not only present in coal and petroleum, it is also found in rocks made from carbonates.

Why do you think carbon forms so many compounds compared to other elements? There are two major reasons for this.

The bonding behaviour of carbon is one reason. Carbon has four electrons in its outer ring available for bonding. Carbon atoms join by sharing electrons to form covalent bonds. This uses one electron from each carbon atom. This leaves three electrons in each carbon atom available for bonding.



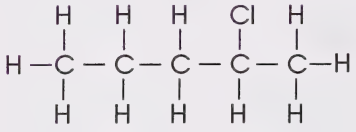
6. Look at the preceding diagram. How many bonding sites does each carbon atom have?

7. How many bonding sites are left in the two carbon atoms shown in the preceding diagram?

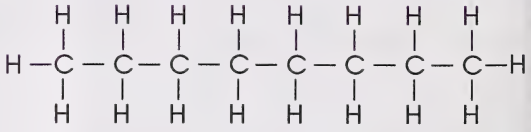
Check your answers by turning to the Appendix, Section 3: Activity 1.

The second reason is that the carbon atom has a unique ability to link and form chains. These chains vary in length and shape. Some chains may be branched and some may be ring-shaped.

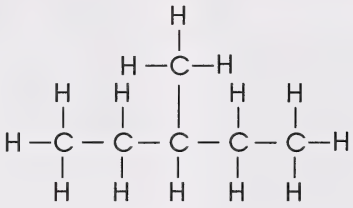
The following molecules are examples of hydrocarbon chains. The number of carbon atoms in the chain can vary from two to several hundred.



In this molecule, five carbon atoms have joined to make a chain.



This has a chain of eight carbon atoms.



Here, six carbons atoms form a branched chain.

The last two molecules shown contain only carbon and hydrogen. They are called hydrocarbons. The first one has one hydrogen substituted with a chlorine atom, so it is considered to be a **hydrocarbon derivative**. In this section you will study only hydrocarbons. Hydrocarbon derivatives make up many of the substances used in producing plastics, synthetic fibres, dyes, paints, detergents, and so on. These substances are commonly referred to as petrochemicals.

hydrocarbon derivative – a hydrocarbon with some other element substituted for a hydrogen atom

One of the properties common to all hydrocarbons is combustion. You will observe some of the properties of combustion in the next investigation.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Investigation: Investigating the Combustion Property of a Hydrocarbon

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

PATHWAYS

If you have access to a bunsen burner, do Part A. If you do not have access to a bunsen burner, do Part B.

Part A

Purpose

Study combustion by observing a number of properties of the flame of a bunsen burner and of a candle.

Materials

- bunsen burner
- candle
- matches
- 2 glass test tubes
- cold water

Procedure

VISIONS

Follow the Procedure section given on page 327 of *Visions* 2.

Observations

8. In a brief paragraph, write what you observed in each case.

Analysis and Interpretation

9. Answer questions 1 and 2 of the Analysis and Interpretation section on page 327 of *Visions* 2.

Check your answers by turning to the Appendix, Section 3: Activity 1.

End of Part A

Part B

Purpose

Study combustion by observing a number of properties of the flame of a candle.

Materials

- candle
- matches
- 2 glass test tubes
- cold water

Procedure

Do Step 4 of the Procedure in Part B on page 327 of *Visions* 2.

Observations

10. In a statement or two, discuss what you observed.

Analysis and Interpretation

11. Do question 2 of the Analysis and Interpretation section on page 327 of *Visions* 2.

Check your answers by turning to the Appendix, Section 3: Activity 1.

End of Part B

Answer the following question based on your observations in the preceding investigation.

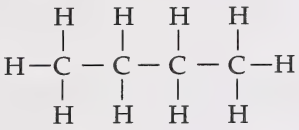
12. What are the products of complete hydrocarbon combustion reactions?

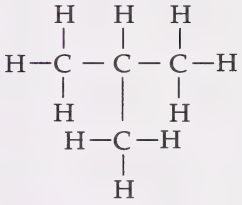
Check your answers by turning to the Appendix, Section 3: Activity 1.

The preceding photograph shows some substances from daily life that are made from hydrocarbons or their derivatives. How can you make sense of the numerous organic compounds used in everyday life? Some organized system of identifying each compound by a specific name and its chemical formula is essential. Chemists have developed a system of nomenclature (naming) for organic compounds. To understand this system, you first need to learn how to write the formulas for organic compounds.

molecular formula – a chemical formula that gives the number of atoms of each element in a molecule

To represent an organic compound, a **molecular formula** is not suitable. Examine the following two hydrocarbons.





13. What is the molecular formula of these compounds?

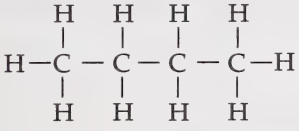
14. How do these compounds differ?

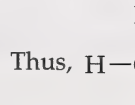
15. Do you expect the two hydrocarbons to have the same properties?

Check your answers by turning to the Appendix, Section 3: Activity 1.

structural formulas – chemical formulas that show how the elements are arranged in terms of the bonding of each atom

Therefore, to represent organic compounds, **structural formulas** are used. Structural formulas show the bonding arrangement of each atom in a molecule. The structural formula for butane is as follows:

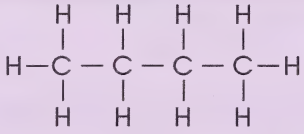
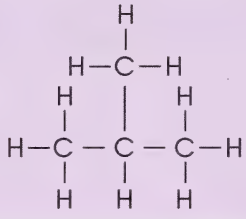
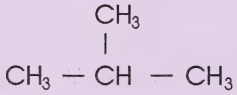


Sometimes a condensed structural formula is used. In this method single bonds between the carbon and hydrogen are omitted while the single bonds and multiple bonds between carbon atoms are shown. Thus,  can also be written as CH_3-.

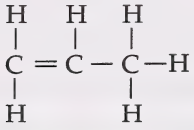
Therefore, the condensed formula for butane would be $CH_3 - CH_2 - CH_2 - CH_3$. In your textbook all single bonds have been omitted in the condensed structural formula. In this module only the single bonds between carbon and hydrogen atoms will be omitted in the condensed formula.

This is summarized in the following table.

TABLE 6.2 STRUCTURAL AND CONDENSED FORMULAS FOR BUTANE AND METHYLPROPANE

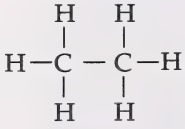
Name	Structural Formula	Condensed Formula	Description
butane		$CH_3 - CH_2 - CH_2 - CH_3$	straight chain molecule
methyl-propane			branched molecule

16. How would you write the condensed formula for the following?

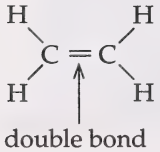


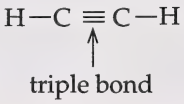
Check your answers by turning to the Appendix, Section 3: Activity 1.

Hydrocarbons may contain only single bonds as in the following molecule.



Or they may contain double or triple bonds as shown in the following molecules.

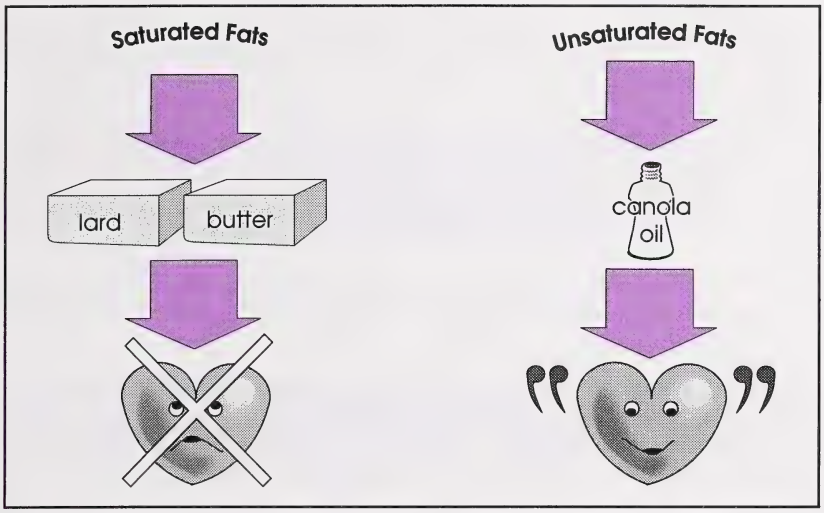




polyunsaturated hydrocarbons – hydrocarbons that contain double or triple carbon-carbon bonds

saturated hydrocarbons – hydrocarbons with only single carbon-carbon bonds

When hydrocarbons contain double or triple bonds between their carbon atoms, they are said to be **polyunsaturated hydrocarbons**. When they have only single bonds, they are **saturated hydrocarbons**. You may have heard that saturated fats are thought to be partly responsible for causing heart disease. Saturated fats can stick to the walls of blood vessels while the polyunsaturated fats usually do not stick.



isomers – compounds having the same chemical formula but different structural formulas

Just like a given number of toy building blocks can be used to build different objects by arranging the blocks differently, a given number of atoms in an organic molecule can be arranged in different ways to form different compounds. These compounds are said to be **isomers** of each other. Examine the following molecules.

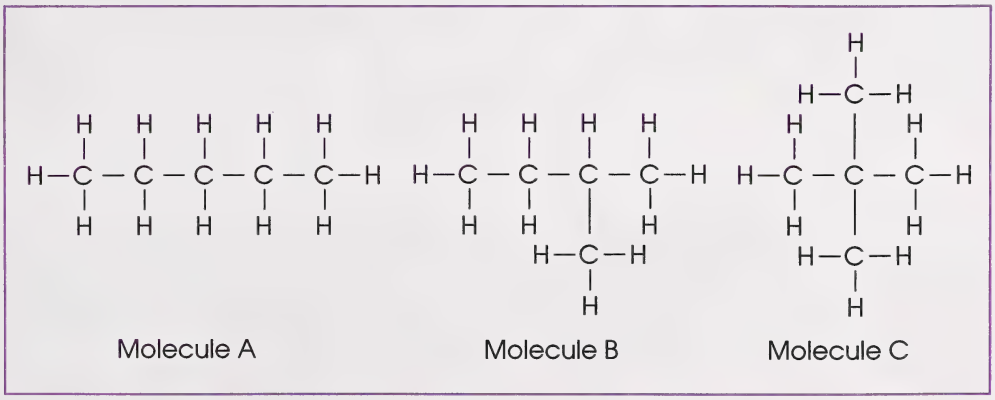


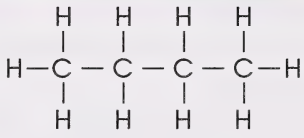
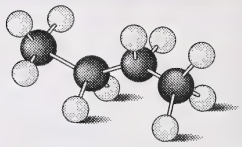
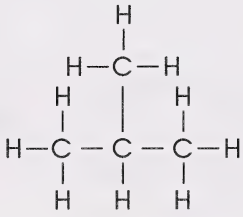
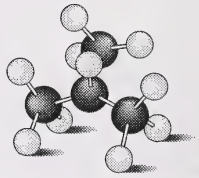
FIGURE 6.1 Isomers

The three molecules in Figure 6.1 have the molecular formula C_5H_{12}; however, they are all different. You can see that the carbon atoms are arranged differently in each of molecules A, B, and C. Molecule A is pentane, molecule B is 2-methylbutane, and molecule C is 2,2-dimethylpropane. Such molecules are said to be isomers of each other. (Note: You will learn what the numbers and prefixes in the names mean later in this section.)

17. Give the molecular formula and the condensed formula for each isomer shown in Figure 6.1.

Check your answers by turning to the Appendix, Section 3: Activity 1.

The following are two other isomers – butane and methylpropane. They are shown with structural formulas and in three-dimensional diagrams. Another name for methylpropane is isobutane.

Name of Compound	Structural Formula	3-D Model
butane		
methylpropane		

VISIONS

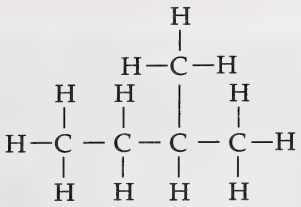
You might be wondering why isomers are important. The melting point of butane is –139°C and that of methylpropane is –160°C. You can see how changing the arrangement of four carbon atoms and ten hydrogen atoms changes the properties of the compounds. For better understanding, refer to Figure 9.4 on page 333 of your textbook; then answer the following questions.

18. What is the minimum number of carbon atoms needed in a molecular formula to produce isomers? Explain.

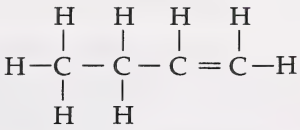
19. What is the relationship between the number of carbon atoms and the number of possible structural isomers?

20. Write the condensed structural formula for each of the following:

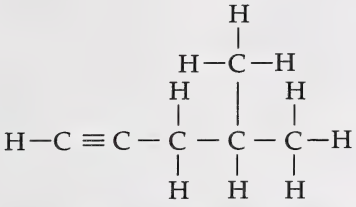
a.



c.



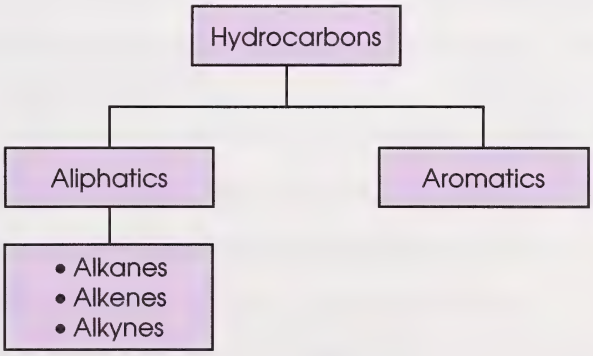
b.



Check your answers by turning to the Appendix, Section 3: Activity 1.

If you have access to the video series *Organic Chemistry 1*, TV Ontario, ACCESS Network, you may view Segment 1, Carbon the Compromise. Pay particular attention to the first half of the video on carbon as the basis of organic compounds and how structural formulas are written. You may be able to obtain this video through your school or local library.

Based on bonding and properties, hydrocarbons have been classified as follows:



You will only study aliphatics in this course.

In this activity you have studied what hydrocarbons are as well as some of their general properties. In the next activity you will study the group of hydrocarbons called alkanes.

Activity 2: Alkanes

Have you ever used a propane stove, a barbecue, or a butane lighter? Both propane and butane belong to a family of hydrocarbons called alkanes. Alkanes are straight or branched hydrocarbons with only single bonds between the carbon atoms. This classifies them as saturated organic compounds. They form the simplest family of organic compounds. To learn more about this family, read the section entitled Alkanes Form a Homologous Series on pages 329 to 331 of your textbook; then answer the following questions.

VISIONS

1. What patterns emerge when you look at Table 9.1 on page 331 of *Visions 2*?

2. Explain the meaning of the term *homologous series* with reference to molecular structure of organic compounds.

3. What is the general formula for alkanes?

4. What prefix would you use for an alkane with five, seven, and nine carbon atoms?

5. Write the formulas for the alkanes containing the following number of carbon atoms.

   a. 11 b. 24 c. 31 d. 54

6. Go to the Practice Problems on page 332 of your textbook and do questions 1 to 5 for additional practice.

Check your answers by turning to the Appendix, Section 3: Activity 2.

You have seen that hydrocarbons and organic compounds can be very complex. Therefore, a systematic way of naming these substances had to be devised. The IUPAC system of nomenclature is used to name all organic compounds. IUPAC stands for International Union of Pure and Applied Chemistry which is an international body that rules on various standards for chemistry throughout the world. All alkanes have names which end with the suffix *-ane*, and straight-chain alkanes are named according to the number of carbon atoms they have.

VISIONS

The first four alkanes have special prefixes which you will have to learn. Alkanes with five or more carbons are named by using the Greek prefixes pent-, hex-, hept-, and so on with the suffix *-ane*. Refer back to Table 9.1 on page 331 of *Visions 2* for a list of the first ten straight-chain alkanes. Check how these alkanes are named.

7. Name the following compounds. Explain why you named each as you did.

   a. $CH_3 - CH_2 - CH_3$

   b. $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$

Check your answers by turning to the Appendix, Section 3: Activity 2.

So far you have seen how to name a straight-chain alkane using a prefix to represent the number of carbon atoms and the ending *-ane* to show it is an alkane. Alkanes with branches are named slightly differently. Because alkanes with branches have carbon atoms added in the branches, the names also have something added to them.

Naming Branched Alkanes

The name of a branched alkane has the following two parts:

- prefixes to indicate branches
- the stem, which is the longest carbon atom chain, to indicate the parent molecule (The chains need not be in a straight line.)

VISIONS

For more information on naming an alkane when the structural formula is given, read Examples 1 and 2 in the Practice Problems section on pages 333 and 334 of your textbook. Then answer the following questions.

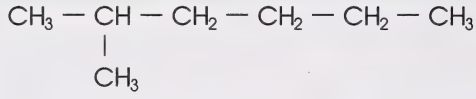
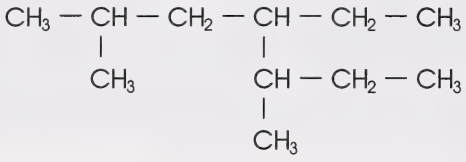
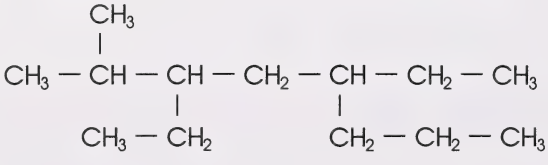
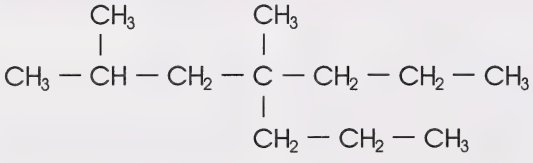
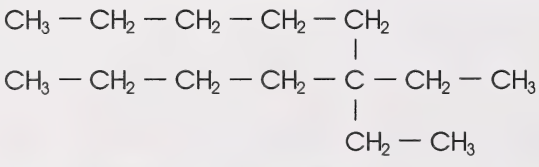
8. a. What is a branch, in terms of a hydrocarbon structure?

   b. How are the names of branches distinguished from the main (parent) chain name?

   c. What do all alkane compound names have in common?

9. How do you know from which end to number the parent chain?

10. Reproduce the following chart. Draw a line through the longest continuous chain of carbon atoms in each molecule and name the parent chain.

Condensed Structural Diagram	Name of Parent Chain
	
	
	
	
	

Check your answers by turning to the Appendix, Section 3: Activity 2.

There are several other important points you need to know when naming organic compounds. They will be illustrated with examples as follows:

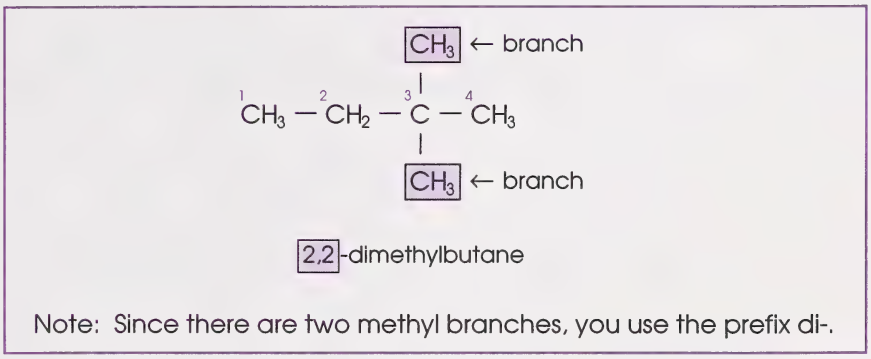
- Both words and numbers are used in organic compound names.

alkyl groups – hydrocarbon chains of the formula C_nH_{2n+1} that act as branches

numbers ← Numbers indicate to which carbon atom of the parent chain the branches or **alkyl groups** are attached. Every branch has to have a number. The numbers of the carbon atoms have been written in the upper left of each carbon atom.

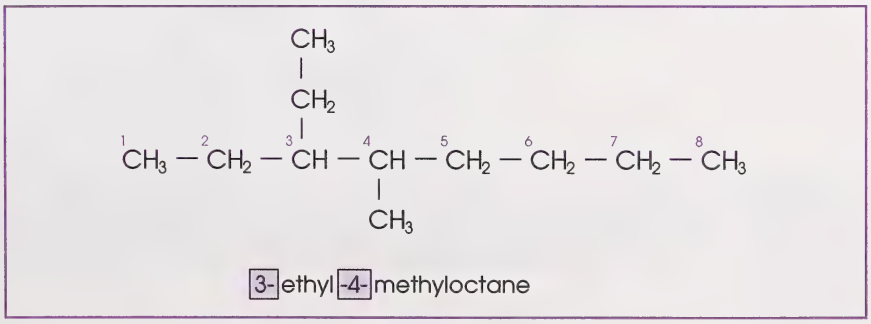
words ← Prefixes in the words of the name indicate how many carbons are contained in the branches (*-yl* ending) and the main chain (*-ane* ending).

- The proper sequence of numbers and words is as follows:
  - numbers always come before the name of the branch or chain to show their location
  - numbers are separated from other numbers by commas

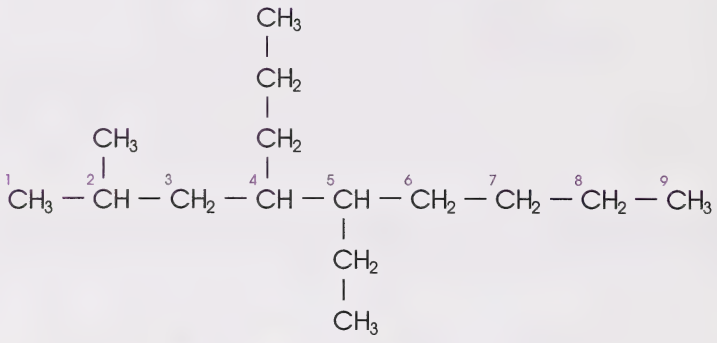


Note: Since there are two methyl branches, you use the prefix di-.

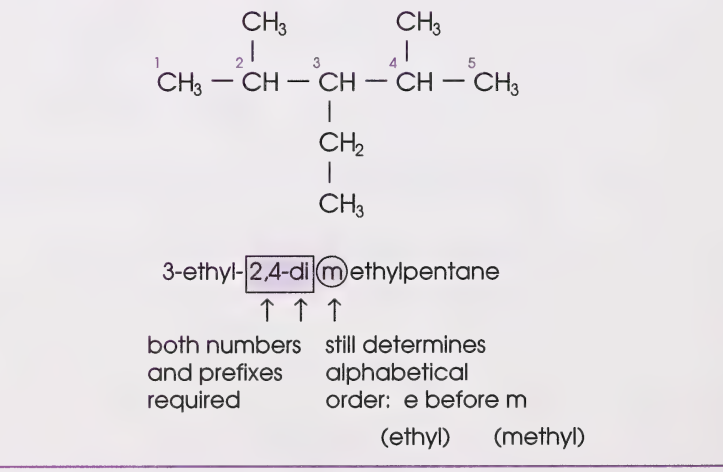
  - numbers are separated from words by hyphens



- Branches are ordered (with their numbers) alphabetically in the name. (At one time, the branches could be ordered by complexity, but this method is no longer used.)



- If there is more than one branch of the same type, a locating number is given to each branch and a prefix indicating the number of that type of branch is attached to the name. This numbering prefix does not affect the alphabetical order of the branches.

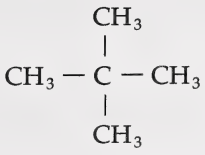


VISIONS

11. Name the following alkanes. Refer back to the previous information and the information on pages 333 and 334 of your textbook if necessary.

a. $CH_3 - CH_2 - CH_2 - CH_3$

b.

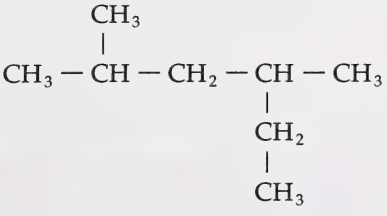


c. $CH_3 - CH(CH_3) - CH_2 - CH_3$

d. $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH(CH_2 - CH_3) - CH_2 - CH_3$

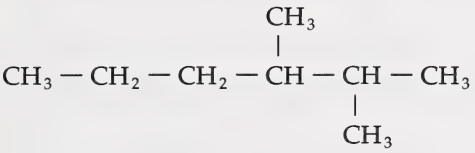
12. For each of the following structures and/or names, describe what is wrong and correct the mistake(s).

a.



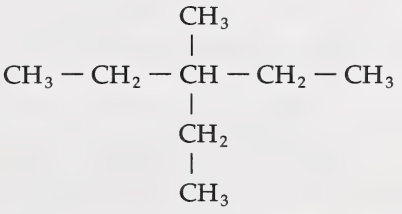
4-ethyl-2-methylpentane

b.



4,5-methylhexane

c.



3-methyl-3-ethylpentane

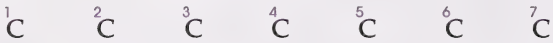
Check your answers by turning to the Appendix, Section 3: Activity 2.

You will often be called upon to show what an organic compound will look like structurally, given its name. When drawing structural diagrams for molecules, you must follow a few simple rules.

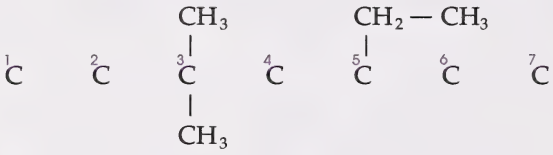
Study how the following structural formula for 5-ethyl-3,3-dimethylheptane has been drawn.

Step 1: Draw the parent chain in a straight line. Since the compound is a heptane, there are seven carbon atoms in the parent chain. Leave enough space between the carbon atoms to add the hydrogen atoms and the bonds (about 1 cm).

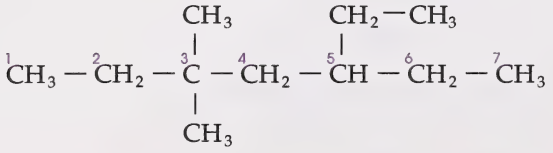
Step 2: There are two methyl groups (CH_3) at carbon atom number 3 and one ethyl group ($CH_2 - CH_3$) at carbon atom number 5. You can start numbering from either left or right. It is common to start from the left and proceed to the right. Write the numbers to the left of the carbon atom so you do not confuse it with the subscript for the number of atoms.



Step 3: Write in the ethyl group and methyl groups at their proper position.

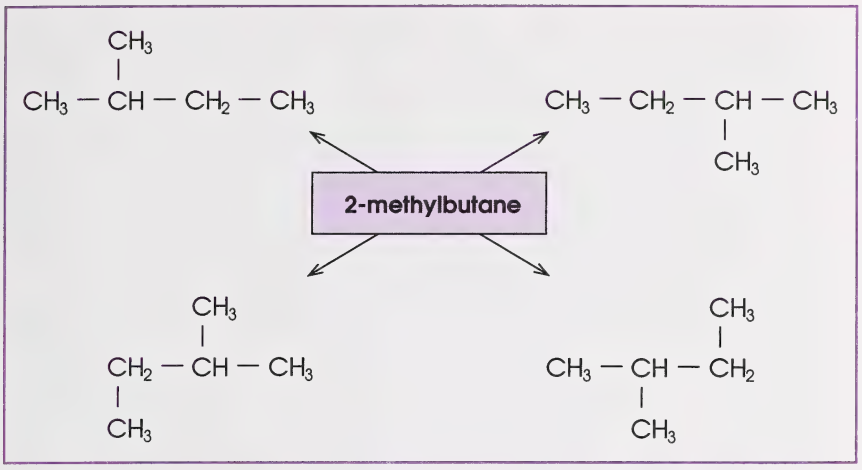


Step 4: Fill in the hydrogen atoms which are attached to the carbon atoms as well as the bonds.



There are a few points to note when drawing structural diagrams.

- The parent chain should be drawn straight to avoid mistakes. Do not put bends in the chain.
- The same structure can be drawn several ways and still be correct. See the example that follows. Check to see that the branches are attached to the correct carbons and that the parent chain is the right length.



13. Draw structural diagrams for the following compounds:

    a. 3-ethyl-3,4-dimethylhexane

    b. 2,2,4-trimethylpentane

VISIONS

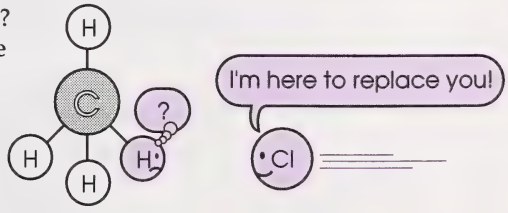
14. Answer questions 1.b., 1.c., and all of question 2 on pages 334 and 335 of *Visions 2* to practise naming compounds and writing structural formulas from IUPAC names.

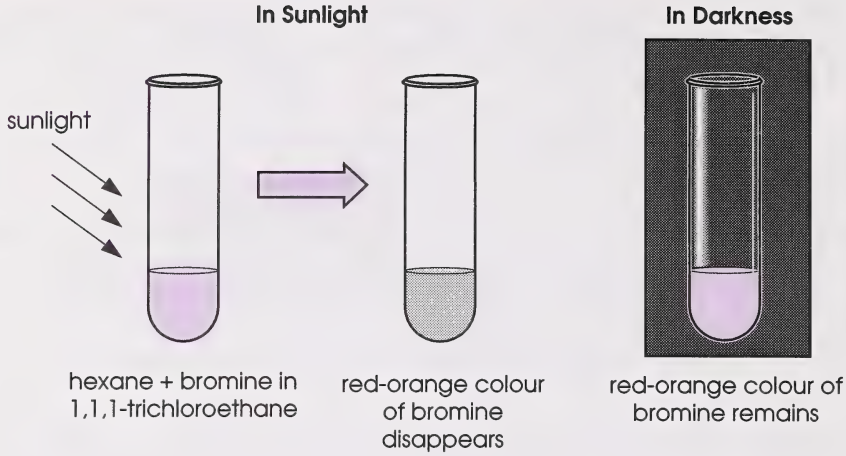
Check your answers by turning to the Appendix, Section 3: Activity 2.

Now that you can name alkanes, you will look at some of their properties. Table 9.1 on page 331 of your textbook gives some physical properties of this family. Alkanes are insoluble in water; and since they are also less dense than water, they float on it.

substitution reaction – a reaction in which a hydrogen atom is replaced by another atom

One of the important chemical properties of alkanes is the **substitution reaction**. You will use hexane as an example to study this property. Have you ever played basketball? Substitution in a basketball game means the replacement of one player by another. Similarly, substitution reactions in organic chemistry involve the replacement of one atom by another. Industry uses this type of reaction to produce many of the organic substances you use today. Hexane reacts with bromine in the presence of sunlight (as shown by the diagram that follows). You know a reaction has occurred by the disappearance of the red-orange colour.





The fact that the colour disappears indicates a reaction occurred. Thus, a reaction occurs in the presence of sunlight but not when done in the dark. All alkanes show no reaction with bromine when in the dark.

What does the previous diagram suggest? It indicates that some sort of energy is needed for this reaction. The reaction is much faster with chlorine as well. Read pages 335 to 337 of your textbook to learn more about this reaction and some other properties of alkanes.

halogenated – having a halogen such as chlorine, bromine, or iodine added by a chemical reaction

15. List some advantages of **halogenated** hydrocarbons.

16. What is a major problem associated with these chemicals?

17. What is being done to reduce the ozone problem associated with chlorinated products?

Check your answers by turning to the Appendix, Section 3: Activity 2.

In Alberta, oil is an important natural, organic resource. It is a source of many important fuels. It is a mixture of short and long chain hydrocarbons. To make the best use of this resource, it needs to be separated into groups that are close in chain length. This process is called refining and is done in plants such as the one in the following photograph.

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VISIONS

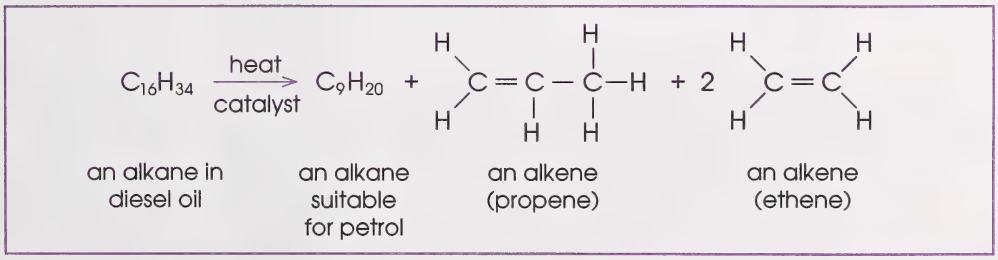
The different compounds are called fractions. The fractions are separated by a method called **fractional distillation**. See Figure 9.1 on page 328 of *Visions 2* for the various fractions that are obtained from crude oil with a fractionating tower.

fractional distillation – a method used to separate the different fractions in crude oil

The relative quantities of the fractions obtained do not measure up to the required market needs. Therefore, heavier fractions are broken into lighter fractions by a process called **catalytic cracking**. In catalytic cracking, a **catalyst** such as aluminum oxide mixed with silicon oxide is added to carry out the reaction at lower temperatures. The heavy fraction is heated in the absence of air. The molecules vibrate faster and this results in the breaking of C-C bonds to produce short chain molecules.

catalytic cracking – the process of breaking down long-chain hydrocarbons to small-chained molecules

The following reaction produces two alkenes which can be used in the polymer industry.



catalyst – a substance that increases the rate of a chemical reaction without being used up in the reaction

For additional information on petroleum refining, read pages 328 and 329 of *Visions* 2.

18. Why is catalytic cracking an important property of alkanes?

19. What is catalytic reforming and how does it differ from catalytic cracking?

20. To review the concepts introduced in this activity, do questions 1 to 4 on page 338 of *Visions* 2.

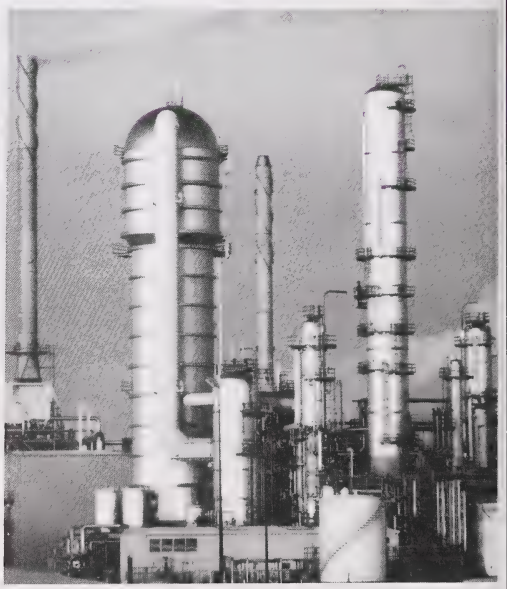
Check your answers by turning to the Appendix, Section 3: Activity 2.

If you have access to the video series *Organic Chemistry 1*, TV Ontario, ACCESS Network, view Segment 4 entitled Fixing Fuels. This segment describes the petroleum refining processes and gives a visual explanation of processes such as catalytic cracking and catalytic reforming. You may be able to obtain this video through your school or local library.

In this activity you have looked at one type of hydrocarbon – alkanes. In the next activity you will study some of the organic compounds produced by the cracking process – alkenes and alkynes.

Activity 3: Alkenes and Alkynes

In the previous activity you looked at the process called catalytic cracking. The results of the cracking process are a multitude of chemicals which are called alkenes and alkynes. Ethene or ethylene, one of the most versatile organic compounds known, is a major product of Alberta's natural gas industry. Unsaturated hydrocarbons are made by cracking alkanes in a cracking unit of an oil refinery (as shown in the photograph). In the previous activity you studied alkanes, which contain only single bonds. In this activity you will study hydrocarbons which have double or triple bonds, which are called alkenes and alkynes respectively.



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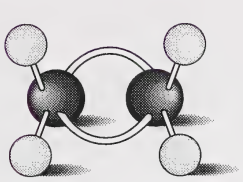
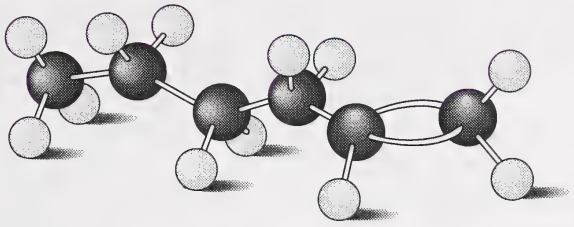
The following diagrams show a three-dimensional view of two alkene molecules .



3-dimensional atomic model of ethene



3-dimensional atomic model of 1-hexene

VISIONS

Read the section entitled Ethene Production in Alberta on page 340 of *Visions 2;* then answer the following questions.

1. a. What is the major use of ethene?

   b. How many of these products can you find around your home?

2. Why is Alberta such a high producer of ethene?

Check your answers by turning to the Appendix, Section 3: Activity 3.

VISIONS

Read some general information about the alkene family starting at Section 9.2 on pages 338 and 339 of your textbook; then answer the questions that follow.

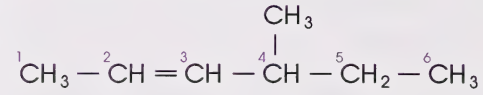
3. What is the general formula of alkenes?

4. How does it differ from the general formula for an alkane?

5. What is the name of the first member of the alkene family? What is its common name? Write its condensed structural formula.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Alkenes are named using the same general rules as those for alkanes. Look at how the following alkene is named.



The numbering of the carbon atoms is from left to right so that the lowest possible number is assigned to the double-bond carbon atom. The number for the double-bond carbon is written next to the parent chain name.

The name for the compound is as follows:

4-methyl-2-hexene

- a methyl group attached to C-4
- carbon-carbon double bond between C-2 and C-3 (The smaller number is assigned.)
- indicates double bond

VISIONS

6. For more information on how to name alkenes, read the rules given on page 339 and the bottom of page 340 of your textbook. Then answer questions 1.a., 1.b., and 2 on page 341.

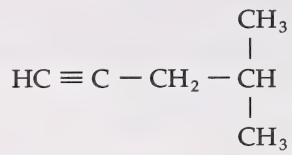
Check your answers by turning to the Appendix, Section 3: Activity 3.

VISIONS

Now you are ready to move on to hydrocarbons which have triple bonds. To learn how to name alkynes, read the section entitled Alkynes Contain Carbon-Carbon Triple Bonds on page 342 of your textbook, and study the example in the Practice Problems section on page 343.

7. How does the general formula for alkynes differ from that of alkenes and alkanes?

8. Name the following compounds.

a. 

b.

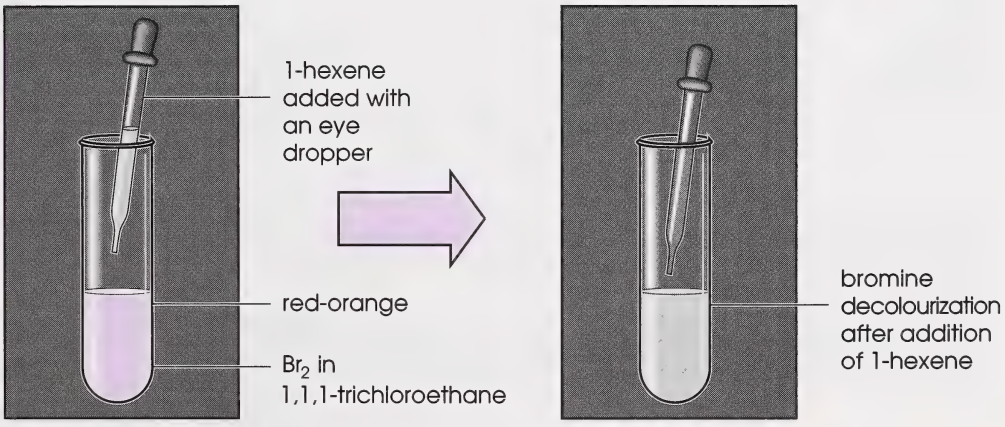
9. Do questions 1.a. and 2 on page 343 of your textbook.

Check your answers by turning to the Appendix, Section 3: Activity 3.

All alkenes and alkynes have similar chemical properties since they are unsaturated hydrocarbons. They all undergo combustion reactions which were discussed in Activity 1 of this section. However, alkenes and alkynes are more reactive compared to alkanes. This is because of the multiple bonds they contain.

addition reaction – a chemical reaction that increases the number of atoms in a molecule

The **addition reaction** is one of the important reactions that alkenes and alkynes experience. The substances that will undergo this type of reaction with unsaturated hydrocarbons are usually halogens or hydrogen. The addition of 1-hexene to bromine dissolved in the solvent 1,1,1-trichloroethane is shown in the following diagram. The bromine in the solvent is a red-orange colour. The reaction is done in the dark.


1-hexene added with an eye dropper
red-orange
Br_2 in 1,1,1-trichloroethane
bromine decolourization after addition of 1-hexene

The previous diagram shows the following addition reaction.

$$\underset{\text{colourless (unsaturated)}}{CH_3 - CH_2 - CH_2 - CH_2 - CH = CH_2} + \underset{\text{red-orange}}{Br_2} \rightarrow \underset{\text{colourless (saturated)}}{CH_3 - CH_2 - CH_2 - CH_2 - CHBr - CH_2Br}$$

In this reaction a colourless solution of 1-hexene reacts with orange-coloured bromine. The bromine atom is added at the double bond of the 1-hexene and the orange colour of the bromine disappears quickly.

Even though this reaction is done in the dark, bromine reacts with 1-hexene. This is indicated by the disappearance of the colour. This reaction with bromine in the absence of light occurs with all alkenes and alkynes (any unsaturated compound).

10. Recall from the previous activity that alkanes would not react with bromine when the reaction was done in the dark. Design a procedure to tell whether a substance is a saturated compound (alkane) or an unsaturated compound (alkene or alkyne). Explain how you would tell which is a saturated compound and which is an unsaturated compound.

Check your answers by turning to the Appendix, Section 3: Activity 3.

An addition reaction occurs when margarine is made from corn oil. Next time you are using margarine, check the label. Does it say "margarine is made from the **hydrogenation** of corn oil"? Or "contains 75% hydrogenated oil"? What does this mean?

hydrogenation – addition of hydrogen to an unsaturated hydrocarbon

The addition of hydrogen to an alkene is called hydrogenation. It is an important application in industry. It is used to change liquid fat to solid fat. In an addition reaction between hydrogen and an alkene, hydrogen atoms are added to the alkene where there is a double bond. Corn oil is an unsaturated compound (an alkene) while margarine is a saturated compound (an alkane).

VISIONS

Read the section entitled Unsaturated Hydrocarbons Take Part in Numerous Chemical Reactions on pages 344 to 346 of your textbook; then answer the following questions.

11. Addition of which molecule produces an alcohol from an alkene?

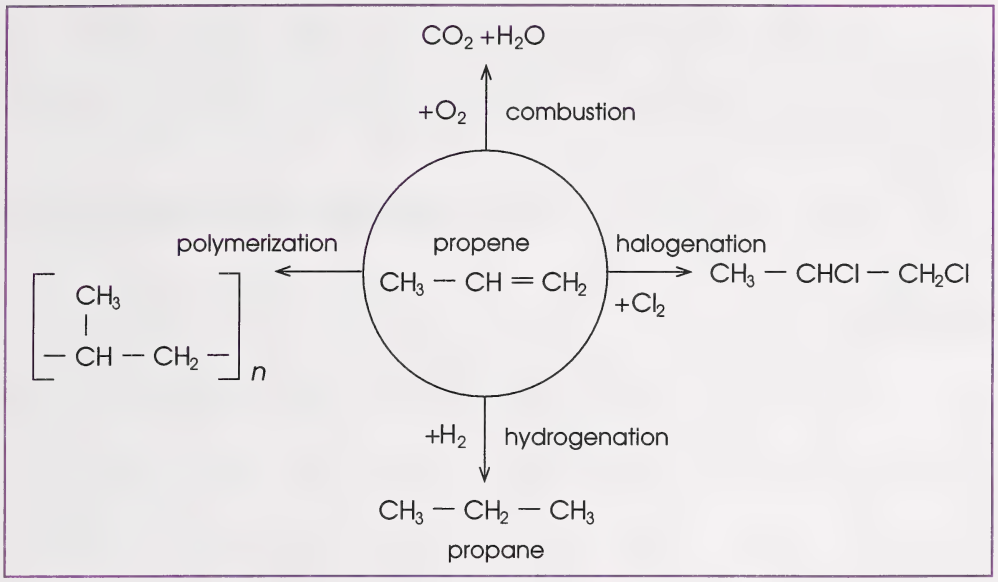
12. State the molecular formula for ethylene glycol, and describe what this substance is used for.

13. What is hydrogenation and what is its commercial application?

14. For further practise do questions 2 to 4 on page 346 of *Visions 2*?

Check your answers by turning to the Appendix, Section 3: Activity 3.

The following figure summarizes some important reactions of alkenes using propene as an example.



So far you have studied three of these reactions. In the next activity you will study the fourth reaction – polymerization.

Activity 4: Polymers

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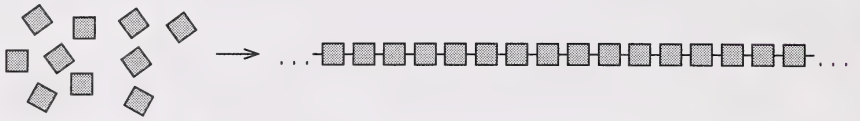
polymers – large organic molecules made from repeating units of smaller molecules

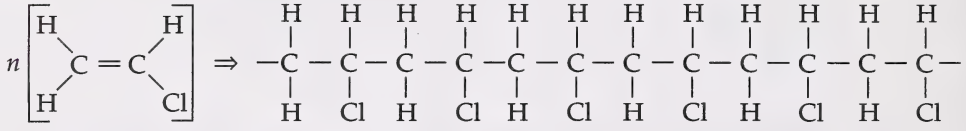
monomers – single repeating units of polymers

The fishing line used in the previous photograph is made from nylon. What does it have in common with a laser disc, a toothbrush, a comb, or a contact lens? They are all **polymers**. This means that they are very long molecules, made by joining repeating units of the same small molecule. The small molecules are called **monomers**.



monomer molecules — part of a very large polymer molecule

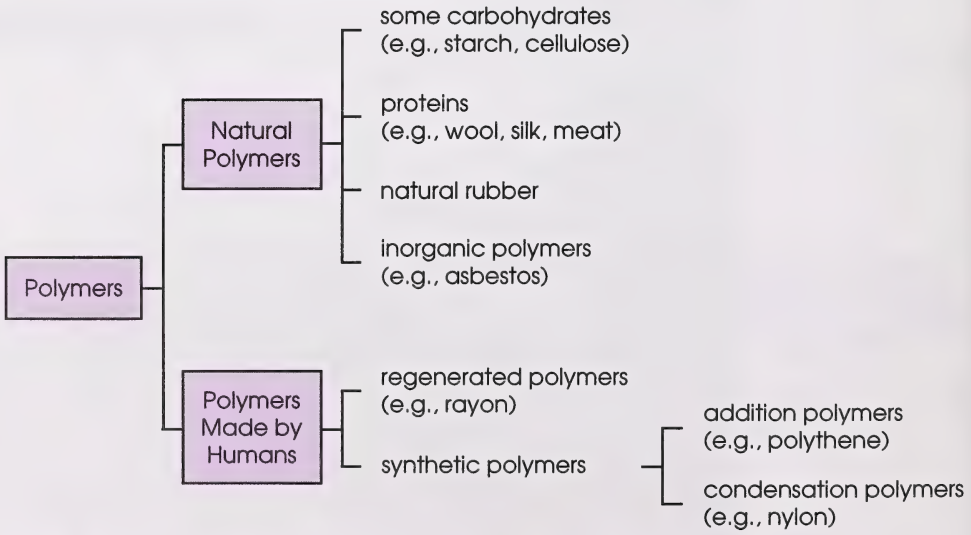
This schematic diagram can be represented by an actual reaction such as the one that follows. A number of vinyl chloride molecules (n) have been combined together to give part of a polyvinyl chloride molecule.



vinyl chloride (monomer) — part of polyvinyl chloride molecule (polymer)

Polyvinyl chloride is one of the products produced at the Dow chemical plant in Fort Saskatchewan, Alberta.

Polymers show up in the natural world and they can be made by humans. The following diagram gives a brief classification of polymers.



Parachutes used to be made from a natural polymer called silk. Silk is a protein produced by silkworms. All protein molecules are polymers. Do you know the name of the monomer in a protein molecule? It is an amino acid. Amino acids are the building blocks of proteins. Silkworms use amino acids to produce this protein called silk fibre. Nylon, which now is used as the material for parachutes, is a polymer made by humans.

Parachutes aren't the only things that are made from polymers. To learn about more uses for polymers, read the section entitled Polymers and Plastics on pages 348 to 352 of your textbook.

1. Silk is a natural polymer. Name two other natural polymers and explain where they are found.

2. What two molecule groups make up an amino acid?

3. Proteins are made up of amino acids. What determines the different functions of proteins?

4. Complex carbohydrates are made up of which common monomer?

plastics – polymers of hydrocarbons which can be moulded into shapes

5. List four properties that make **plastics** so useful.

6. Why were a number of products like celluloid, rayon, and nylon discovered?

Check your answers by turning to the Appendix, Section 3: Activity 4.

Plastics contain some of the largest organic molecules. Some examples of plastics and their uses are given in the following table.

TABLE 6.5 SOME PLASTICS AND THEIR USES

Type of Plastic	Purpose
melamine	unbreakable dishes and mugs, ashtrays
nylon	rope, bristle for brushes, tights, clothing
phenolic	electric plugs, saucepan handles
polystyrene	plastic cups, packaging materials
polythene	plastic bags, dustbins, plastic basins
polyvinyl chloride (PVC)	raincoats, seat covers, records, water pipes

VISIONS

Read the section entitled Different Plastics Have Different Properties on page 354 of *Visions 2*; then answer the following questions. Refer to figure 9.12 on page 355 of your textbook as well.

7. Give three examples of thermoplastics.

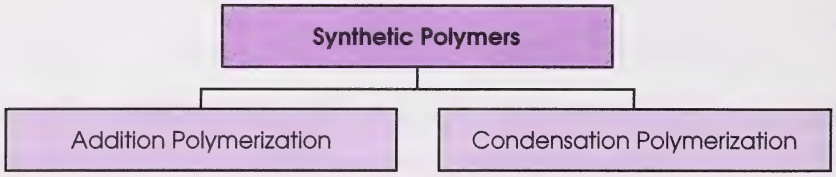
8. Why are thermoplastics not used for making saucepan handles?

9. How are thermosets different from thermoplastics?

10. Explain why thermosets keep their shape after being heated the first time.

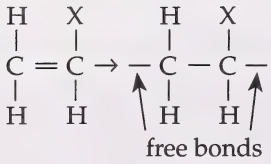
Check your answers by turning to the Appendix, Section 3: Activity 4.

There are two types of processes commonly used to prepare synthetic polymers.

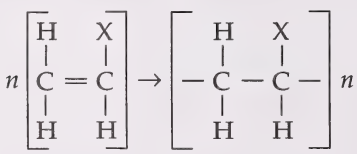


Addition Polymerization

In this type of polymerization, monomer molecules join together to form a polymer without removal of small molecules.



As shown in the previous diagram, the carbon-carbon double bond is opened so that the monomer molecule will have two free bonds which can join to other molecules. The general equation for this reaction can be written as follows:



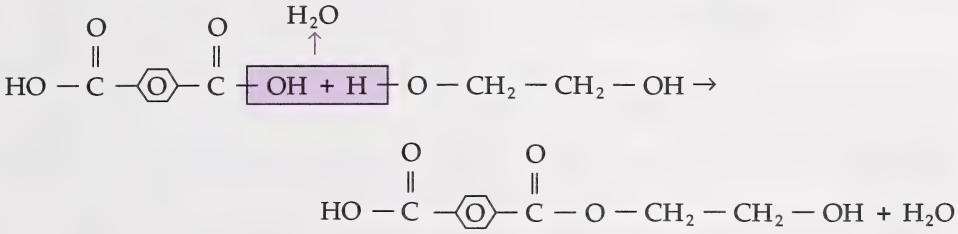
Note: X represents an atom or a group of atoms like $-H$, $-CH_3$, and so on. Also, n is the number of molecules of the monomer as well as the number of repeating units in the polymer chain.

Condensation Reaction

This is a reaction in which monomers join to form a polymer with elimination of small molecules.

Start with two reactants such as the ones that follow.

The two OH groups join together to form water.



The two molecules have now combined to form a longer chain molecule and water. This process can be repeated many times to form very long chain molecules.

VISIONS

Read the information given on pages 353 and 354 of *Visions 2* to learn more about these reactions. Answer the following questions.

11. Give an example of materials produced by both condensation reactions and addition reactions.

12. Which industry is presently providing many of the monomers required for the production of plastics.

To find out how plastics differ, do the following investigation.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Investigation: Comparing Plastics

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

VISIONS

Read Activity 9.3 on pages 355 and 356 of *Visions 2*.

Purpose

13. State the purpose of this investigation.

Background Information

Obtain as many samples of the plastics listed on page 355 of *Visions 2* as you can. Refer to table 9.5 on page 353 to help you recognize the different samples.

Materials

- The materials are listed on page 355 of *Visions 2*.
- You will need the list of materials in the second column only if you have access to a fume hood and have decided to do the heating test (Part c of the procedure on page 356 of *Visions 2*).

Procedure

- Make a chart like the one in the Observations section to record what you observe about each type of material.

- Follow the procedure given on pages 355 and 356 of your textbook. Follow the chart on page 356 with each sample.
- Do not heat or burn the plastic sample unless you can do this in a laboratory fume hood or outside. Heating or burning plastics may release toxic fumes.
- The results of heating the various samples have been provided in the observations chart.

Observations

14. Complete the chart.

Substance	Rigidity	Floats in Water	Marks with HB Pencil	Heat
polyethylene				melts
polypropylene				burns with green flame on copper wire
cellulose acetate				smoke smells like vinegar
polystyrene				no green colour with copper; no ash on heating
nylon				no smoke; ash left
acrylic				no smoke; no ash

Analysis and Interpretation

15. Do questions 1 to 4 in the Analysis and Interpretation section on page 356 of *Visions 2*. You may have to research the answers to questions 3 and 4.

Check your answers by turning to the Appendix, Section 3: Activity 4.

VISIONS

Polymers are a large part of your life. Articles made from polymers are evident everywhere. The demand for plastics has grown immensely over the last decade. This has resulted in a large number of careers in the plastics industry. Read the article Careers in Plastics on page 357 of *Visions 2;* then answer the following questions.

16. The plastics industry offers employment for university graduates, technical school graduates, as well as some employees who may train on the job. List two university graduate careers and two technical school graduate careers, and briefly describe what their job in the plastics industry would involve.

17. Write a short essay on which career you would choose and why such work might interest you.

VISIONS

18. To review this activity, do questions 1 to 3 on page 358 of your textbook.

Check your answers by turning to the Appendix, Section 3: Activity 4.

If you have access to the video series *Organic Chemistry 1*, TV Ontario, ACCESS Network, view Segment 5 entitled Polyethylene. This video outlines one type of polymerization process and gives you an idea of the many applications for polymers. You may be able to obtain this video through your school or local library.

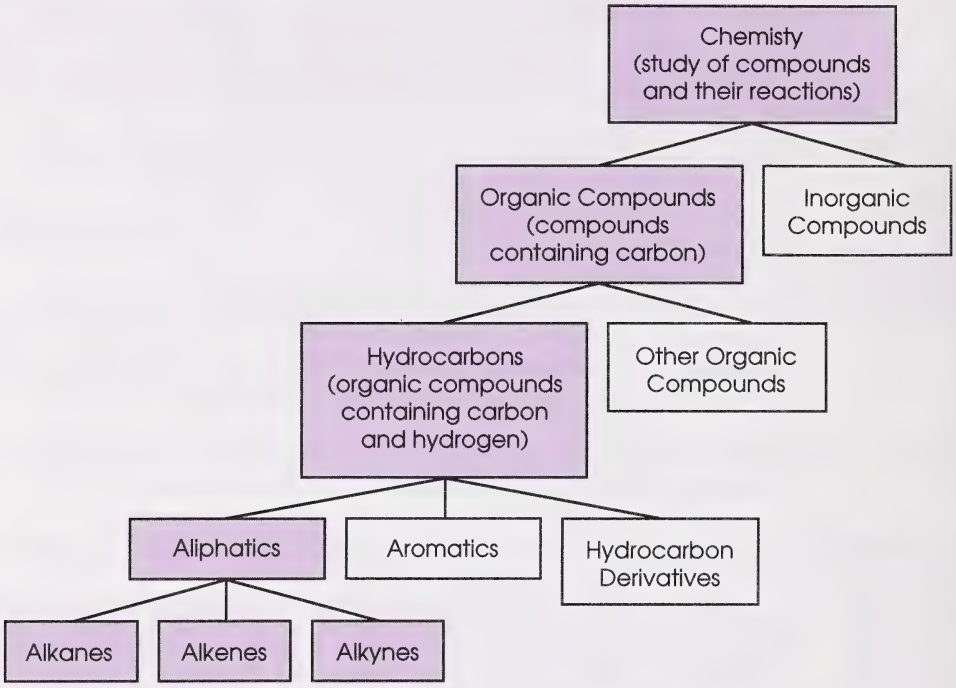
In this activity you have learned about long-chain molecules which make up substances called polymers. Polymers can be natural or made by humans. The most familiar polymers made by humans are plastics.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Study the following diagram for a visual picture of how the various groups of compounds you studied in this section are related to chemistry. The ones you studied in this section are coloured.



1. Answer either true or false for the following statements.

   a. A hydrocarbon is an organic compound.

   b. An alkyne is an aromatic compound.

   c. Alkanes are hydrocarbons.

   d. Alkenes are aliphatics.

   e. Alkanes, alkenes, and alkynes are organic compounds.

2. Which of the following compounds are hydrocarbons?

- C_2H_4
- CO_2
- $CaCO_3$
- H_2O
- C_4H_{10}

Check your answers by turning to the Appendix, Section 3: Activity 4.

VISIONS

Review the rules for naming alkanes, alkenes and alkynes on pages 333 to 334, 339 to 340, and 342 of *Visions 2* as well as the appropriate parts in this section; then do questions 3, 4, and 5.

3. Write the molecular formula and the structural formula for each of the following hydrocarbons.

a. pentane

b. 1-butene

c. ethyne

d. methylpropane

e. 2-methyl-3-heptene

4. What are the general formulas for alkanes, alkenes, and alkynes?

5. Write the names for each of the following compounds given.

a. $CH_3 - CH_2 - CH = CH - CH_3$

b. $CH_3 - C \equiv CH$

c.
$$CH_3 - CH_2 - CH_2 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$$

d. $CH_3 - CH = CH_2$

e.
$$CH_3 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_2 - CH = CH_2$$

f.
$$CH_3 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$$

6. Isomers are compounds that have the same molecular formula but different structural formula. Which of the following structural formulas are isomers?

A. $CH_3 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$

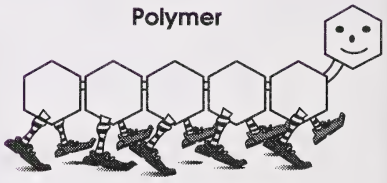
B. $CH_3 - CH_2 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH_2}}$

C. $CH_3 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_2 - CH_3$

D. $CH_3 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$

7. Alkanes are less reactive and undergo substitution reactions, whereas alkenes are more reactive and undergo addition reactions. What is the difference between the two reactions?

Have you ever taken dandelions and removed the flowers to make a chain out of the stems? This is very much like a polymer – a chain of repeating units. Each individual stem would be like a monomer. Polymers play an integral part in the function of life systems and have revolutionized the way society functions.



8. Explain the difference between a polymer and a monomer in terms of molecules?

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Do any two of the following three questions.

1. Plastics, unlike natural materials, are nonbiodegradable. Once dumped into the environment, they stay there almost forever. Do some research to find solutions to this problem.

2. Find out what effect burning low grade coal has on the environment. Write three sets of equations to describe this effect.

VISIONS

3. Do question 2 in the Decide section on page 362 of *Visions 2*.

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

In this section you have discovered that hydrocarbons contain only two elements: carbon and hydrogen. Even though substances containing these elements originally came from natural resources, they are now frequently synthesized in a laboratory. They undergo a variety of reactions which allows for the formation of thousands of different organic compounds. Scientists can build compounds of desired characteristics by controlling the size of the molecules.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 3.

MODULE SUMMARY

In Sections 1 and 2 you learned about redox reactions. Redox reactions involve two-way electron transfer – an oxidation reaction in which electrons are lost and a reduction reaction in which electrons are gained. The spontaneous conversion of metals to their oxides or salts is a redox reaction called corrosion. You are most familiar with the corrosion of iron, commonly known as rusting.

Redox reactions can produce or consume electricity. Redox reactions which produce electricity can be used to make batteries. Redox reactions which consume electricity can be used to electroplate objects or to produce or purify metals.

In Section 3 you learned about a class of compounds called organic compounds. Organic compounds include all compounds which contain carbon, while those compounds containing carbon and hydrogen are called hydrocarbons.

You learned how to write the structural and condensed formulas for three types of hydrocarbons: alkanes, alkenes, and alkynes. Alkanes contain only single carbon-carbon bonds and are called saturated compounds. Alkenes and alkynes contain double and triple carbon-carbon bonds and are called unsaturated compounds.

Plastics are long-chain molecules made of repeating units. Most compounds for plastics come from the petrochemical industry making Alberta the biggest producer in Canada of starting materials for plastics. Plastics are one of the most important materials used today but present a disposal problem.

The knowledge you have gained from this module will help you understand the functioning of some of the things used in everyday life situations as well as some of the issues associated with their use.

Appendix

Glossary

Suggested Answers

Glossary

activity series: a list of elements showing the relative ability of an element to replace other elements in a reaction

addition reaction: a chemical reaction that increases the number of atoms in a molecule

alkyl groups: hydrocarbon chains of the formula C_nH_{2n+1} that act as branches

catalyst: a substance that increases the rate of a chemical reaction without being used up in the reaction

catalytic cracking: the process of breaking down long-chain hydrocarbons to small-chain molecules

coating: the process of covering a surface with paint, plastic, grease, and so on

corrosion: the oxidation of metal atoms to metal ions through the loss of electrons

electrochemical reaction: a chemical reaction in which electrons are exchanged in the reactants

electrochemical cell: a system made from electrodes and electrolytes in which a spontaneous redox reaction produces an electric current; also called a galvanic cell or a voltaic cell

electrode: a solid conductor used in an electrochemical cell to make electrical contact

electrolysis: a process that produces a chemical change by using an electric current

electrolytic cell: a cell in which non-spontaneous chemical changes occur through the application of an electric current

electroplating: a process of coating a surface with a metal using an electric current

fractional distillation: a method used to separate the different fractions in crude oil

galvanic cell: a system made from electrodes and electrolytes in which a spontaneous redox reaction produces an electric current; also called an electrochemical cell

galvanization: the process by which iron is given a protective coating of zinc

half-reactions: the oxidation or reduction reaction parts of redox reactions

halogenated: having a halogen such as chlorine, bromine, or iodine added by a chemical reaction

hydrocarbon derivative: a hydrocarbon with some other element substituted for a hydrogen atom

hydrogenation: addition of hydrogen to an unsaturated hydrocarbon

isomers: compounds having the same chemical formula but different structural formulas

molecular formula: a chemical formula that gives the number of atoms of each element in a molecule

monomers: single repeating units of polymers

organic compounds: compounds which contain carbon

oxidation: a chemical change that involves the loss of electrons by an atom or an ion

plastics: polymers of hydrocarbons which can be moulded into shapes

polymers: large organic molecules made from repeating units of smaller molecules

polyunsaturated hydrocarbons: hydrocarbons that contain double or triple carbon-carbon bonds

redox reaction: a reaction involving transfer of electrons

reduction: a chemical change that involves the gain of electrons by an atom or an ion

sacrificial protection: a process of protecting one metal from corrosion by coating or connecting to a metal that is higher on the activity series

saturated hydrocarbons: hydrocarbons with only single carbon-carbon bonds

structural formulas: chemical formulas that show how the elements are arranged in terms of the bonding of each atom

substitution reaction: a reaction in which a hydrogen atom is replaced by another atom

Suggested Answers

Section 1: Activity 1

1. Examples of redox reactions from everyday life include the following:

   - burning of gasoline in an automobile
   - fruits turning brown when exposed to air
   - dyes used to colour hair
   - cell respiration
   - corrosion of metals
   - extraction of metals from ores

2. a. $2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$ b. $Cl_{2(g)} + 2e^- \rightarrow 2Cl^-$ $2Na_{(s)} \rightarrow 2Na^+ + 2e^-$

3. Oxidation half-reactions have the electrons (e^-) on the products side of the equation since the atom or ion is giving up electrons.

4. The electrons are on the reactants side in reduction reactions since the atom or ion is gaining electrons.

5. The oxidation half-reaction shows electrons on the product side, indicating electron loss. The reduction half-reaction shows them on the reactant side, showing electron gain.

6. It is impossible to have either half-reaction by itself. In order for oxidation and reduction half-reactions to occur, a transfer of electrons from the substance being oxidized to the substance being reduced must occur.

7. a. reduction b. oxidation c. reduction d. oxidation

8. **Textbook question 1(a):** $Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$

   Textbook question 1(b): $Li_{(s)} \rightarrow Li^+_{(aq)} + e^-$

   Textbook question 3: The balanced equation is $Mg_{(s)} + 2AgNO_{3(aq)} \rightarrow 2Ag_{(s)} + Mg(NO_3)_{2(aq)}$.

   Unit Analysis Method

   Calculate the number of moles of $Mg_{(s)}$.

   $$\text{molar mass} = 24.31\,\text{g/mol}\ Mg_{(s)}$$

   $$5.0\,\cancel{\text{g Mg}} \times \frac{1\,\text{mol}\ Mg_{(s)}}{24.31\,\cancel{\text{g Mg}}_{(s)}} = 0.2057\,\text{mol}\ Mg_{(s)}$$

   Formula Method

   data: $m_{(Mg)} = 5.0\ \text{g}$

   $M_{(Mg)} = 24.31\ \text{g/mol}$

   $M_{(Ag)} = 107.87\ \text{g/mol}$

   $n_{(Mg)} = ?$

   $n_{(Ag)} = ?$

   $m_{(Ag)} = ?$

Calculate the number of moles of $Ag_{(s)}$.

$$0.2057 \cancel{\text{ mol Mg}_{(s)}} \times \frac{2 \text{ mol Ag}_{(s)}}{1 \cancel{\text{ mol Mg}_{(s)}}} = 0.4114 \text{ mol Ag}_{(s)}$$

Calculate the mass of $Ag_{(s)}$.

$$\text{molar mass} = 107.87 \text{ g/mol Ag}_{(s)}$$

$$0.4114 \cancel{\text{ mol Ag}_{(s)}} \times \frac{107.87 \text{ g Ag}_{(s)}}{1 \cancel{\text{ mol Ag}_{(s)}}} = 44 \text{ g Ag}_{(s)}$$

(2 significant digits)

solution:

$$n = \frac{m}{M}$$

$$n_{(Mg)} = \frac{5.0 \text{ g}}{24.31 \text{ g/mol}}$$

$$= 0.2057 \text{ mol}$$

$$n_{(Ag)} = 0.2057 \text{ Mg}_{(s)} \times \frac{2 \text{ mol Ag}_{(s)}}{1 \text{ mol Mg}_{(s)}}$$

$$= 0.4114 \text{ mol Ag}_{(s)}$$

$$m = nM$$

$$m_{(Ag)} = 0.4114 \text{ mol} \times 107.87 \text{ g/mol}$$

$$= 44 \text{ g (2 significant digits)}$$

Note: The subscripts indicate which substance is involved in the calculation.

This is how the solution can be set up all in one calculation. This is actually the unit analysis method done on one line.

$$5.0 \cancel{\text{ g Mg}} \times \frac{1 \cancel{\text{ mol Mg}}}{24.31 \cancel{\text{ g Mg}}} \times \frac{2 \cancel{\text{ mol Ag}}}{1 \cancel{\text{ mol Mg}}} \times \frac{107.87 \text{ g Ag}}{1 \cancel{\text{ mol Ag}}} = 44 \text{ g Ag (2 significant digits)}$$

Note: The answer to each step is rounded. However, the final answer is calculated with all the digits carried in the calculator. You may want to review the rules for significant digits in Appendix C of *Visions* 2.

9. sodium, magnesium, iron, copper, gold
(Sodium is most reactive.)

10. There are other elements in Table 8.2. However, the elements sodium, magnesium, iron, copper, and gold are in the same order from most reactive to least reactive.

11. Your observation chart should look like the one that follows:

	$Zn(NO_3)_{(aq)}$	$AgNO_{3(aq)}$	$Cu(NO_3)_{(aq)}$	Water
$Zn_{(s)}$	no	yes	yes	no
$Ag_{(s)}$	no	no	no	no
$Cu_{(s)}$	no	yes	no	no

Yes indicates a reaction occurred, and no indicates no reaction occurred.

12. **Textbook question 1:** A chemical reaction occurs if there is a colour change, an energy change, or precipitate formation.

    The zinc metal darkens and a solid forms in both the silver nitrate and the copper nitrate solutions. In copper nitrate, the blue colour disappears over time. Zinc metal shows no change in the zinc nitrate solution or the water.

    The silver metal shows no evidence of change in any solution.

    The copper metal shows a precipitate forming on it in silver nitrate, and a blue colour forms in the solution. The copper metal shows no apparent change in any of the other solutions.

    Textbook question 2: From most reactive to least reactive, the solutions are silver nitrate, copper nitrate, and zinc nitrate.

    From most reactive to least reactive, the metals are zinc, copper, and silver.

    Textbook question 3: Silver would be best suited because it is the least reactive.

    Textbook question 4: The metals are rubbed with steel wool to make sure that the surfaces of the metals are clean. Most metals react with oxygen in the air, producing an oxide on the surface. This oxide must be removed so new metal is exposed.

    Textbook question 5: The order in the list is the same as the order in the activity series.

    Textbook question 6: Iron will displace silver in the silver nitrate solution, and silver will be deposited in the container.

    Textbook question 7: Iron objects are usually coated with zinc or chromium because they are more reactive compared to iron. Therefore, the iron is protected from corroding because the zinc or chromium reacts with air first. Zinc coating is more common because it is less expensive.

13. Refer to the answers provided for Section 1, Activity 1, question 12.

14. Copper is more reactive. Because the $Cu_{(s)}$ becomes Cu^{2+} ions as shown by the blue colour of the solution on the right, it is the copper metal that is reacting. The silver metal collects and coats the wire. Therefore, it is less reactive.

15. A metal will always displace a less reactive metal from solutions of its compounds.

Section 1: Activity 2

1. $4Fe_{(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)}$

2. Iron is oxidized and oxygen is reduced. (Note: You are told in the textbook on page 302 that iron is oxidized. Since one substance is oxidized and the other is reduced, you know the oxygen must be reduced.)

3. Water and the dissolved salts act as an electrolyte through which the electrons can move.

4. Your fingers get black from handling aluminum windows because the oxide rubs off easily.

5. You can make the iron more corrosion-resistant by putting a coating such as paint or grease that does not allow the iron to corrode by protecting it from moisture and air. You can also put a metal coating on that does not corrode easily.

6. The observation charts should look as follows:

	Beaker 1 (untreated nail in tap water)	Beaker 2 (galvanized nail in tap water)	Beaker 3 (piece of metal can in tap water)
Day 1	some rust showing	no rust	rust showing around edges
Day 2	more rust	no rust	rust around edges
Day 3	most of rust crusted around nail (large flakes of rust)	no rust	larger flakes than in $NaCl_{(aq)}$

	Beaker 1 (untreated nail in $NaCl_{(aq)}$)	Beaker 2 (galvanized nail in $NaCl_{(aq)}$)	Beaker 3 (piece of metal can in $NaCl_{(aq)}$)
Day 1	some rust showing (water is browner than tap water)	no rust	rust around edges
Day 2	more rust	no rust	rust around edges
Day 3	more rust – rust more evenly spread out than in tap water (fine rust)	no rust	rust around edges (fine rust)

	Jar 1 (untreated nail and galvanized nail in boiled tap water)	Jar 2 (untreated nail and galvanized nail in boiled $NaCl_{(aq)}$)
Day 1	no rust on either nail	no rust on either nail
Day 2	no rust on either nail	no rust on either nail
Day 3	no rust on either nail	no rust on either nail

7. **Textbook question 1:** The nail in Beaker 1 containing sodium chloride solution rusted the fastest as well as the most extensively.

Textbook question 2: The nails in the mason jars rusted more slowly and had less rust after three days than the nails in the beakers. You may have no rust on the nails in the jars.

Textbook question 3: Air is essential for rusting because the nails in the mason jars rusted very little compared to the nails in the beakers. This is because the mason jars do not have air since they have been heated. This drives the air out.

Textbook question 4: The presence of salt increases the rate of rusting.

Textbook question 5: Galvanization protects the nail as long as zinc covers the surface totally.

Textbook question 6: Rusting occurred on the edges where a cut was made because the iron was exposed.

8. Your observations chart may look like the one that follows:

Time	Nail with Zn	Nail with Pb	Nail with Cu	Nail with Ag
1 h	no rust	shows some rust	shows rust within 1 hour (more than with lead)	shows rust within 1 hour (more rust than lead or copper)
2 h	no rust	less rust than with copper	more rust showing	more rust, water is quite brown
24 h	no rust, white film between zinc and iron nail	water lighter in colour than with copper, crusts of rust about 0.5 cm up the nail	water is quite brown, crusts of rust about 2 cm up nail	water is very brown, crusts of rust covers most of the nail

Note: Follow the column with lead (Pb) if you used lead. Follow the column with silver (Ag) if you used silver.

9. **Textbook question 1:** The nail corrodes when connected to a copper, lead, or silver strip. The reaction takes less time with lead and silver compared to copper. The nail does not corrode when connected to the zinc strip. This is because zinc is higher than iron in the activity series and reacts faster than iron, whereas copper, lead, and silver are below iron in the activity series. Silver reacted the most and is the furthest below iron in the activity series table.

Textbook question 2: Answers may vary. Methods of reducing corrosion in cars include the following:

- coating the steel with zinc
- replacing the steel with other materials like fibreglass
- reducing exposure to salt
- improving the quality of paint, laquer, or other coatings
- running a low voltage over the entire car to resist normal electron transfer
- using non-metal materials in high corrosion areas such as splash guards, front and rear bumper areas, and so on

Textbook question 3: Ceramic and glass are heavy and chip easily. Plastic cannot withstand the heat.

10. Rust develops quickly because the drops of water acts as tiny electrochemical cells on the surface of the metal, thus causing a reaction to occur at the point of contact.

11. The name given is corrosion.

12. The three methods are electroplating, galvanization, and cathodic (sacrificial) protection.

13. Cathodic protection is a process which uses a metal like magnesium to prevent the corrosion of iron.

14. Cathodic protection is also called sacrificial protection since one metal is sacrificed to protect the other.

15. Zinc and magnesium both react more readily compared to iron.

16. A coating can be grease, paint, lacquer, and so on whereas galvanization means dipping the object in molten zinc and then allowing it to cool. Sacrificial protection does not involve any coating. Instead, the attachment of a more reactive metal piece to the object provides protection.

17. **Textbook question 1:** Reactions will occur in a, b, and e. The balanced equations are as follows.

    a. $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

    b. $Zn_{(s)} + 2AgNO_{3(aq)} \rightarrow Zn(NO_3)_{2(aq)} + 2Ag_{(s)}$

    e. $Mg_{(s)} + 2H_2O_{(l)} \rightarrow Mg(OH)_{2(s)} + H_{2(g)}$

    Textbook question 2: Transfer of electrons always occurs in redox reactions.

    Textbook question 3: Answers may vary. Three examples of redox reactions are the burning of wood, the digestion of food in the human body, and the making of wine.

    Textbook question 4: The balanced equation for the reaction is $4Fe_{(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)}$. The half-reactions for oxidation of iron are $2Fe \rightarrow 2Fe^{3+} + 6e^-$ and $3O_{2(g)} + 6e^- \rightarrow 6O^{2-}$. Therefore, a total of twelve electrons per formula unit are transferred when iron rusts.

    Textbook question 5: The statement is false because non-spontaneous reactions require energy input in the form of electrical energy.

Textbook question 6: $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$

Unit Analysis Method

Calculate the number of moles of $H_{2(g)}$.

$$\text{molar mass} = 2.02\ \text{g/mol}\ H_{2(g)}$$

$$1.00\times10^6\ \text{g}\ H_{2(g)} \times \frac{1\ \text{mol}\ H_{2(g)}}{2.02\ \text{g}\ H_{2(g)}} = 4.9505\times10^5\ \text{mol}\ H_{2(g)}$$

Calculate the number of moles of $H_2O_{(l)}$.

$$4.9505\times10^5\ \text{mol}\ H_{2(g)} \times \frac{2\ \text{mol}\ H_2O_{(l)}}{2\ \text{mol}\ H_{2(g)}} = 4.9505\times10^5\ \text{mol}\ H_2O_{(l)}$$

Calculate the mass of $H_2O_{(l)}$.

$$\text{molar mass} = 18.02\ \text{g/mol}\ H_2O_{(l)}$$

$$4.9505\times10^5\ \text{mol}\ H_2O_{(l)} \times \frac{18.02\ \text{g}\ H_2O_{(l)}}{1\ \text{mol}\ H_2O_{(l)}} = 8.92\times10^6\ \text{g}\ H_2O\ \text{(3 significant digits)}$$

Note: All digits in the calculator are carried through the steps.

Formula Method

data: $m_{(H_2)} = 1.00\times10^6$ g

$M_{(H_2)} = 2.02$ g / mol

$M_{(H_2O)} = 18.02$ g / mol

$n_{(H_2)} = ?$

$n_{(H_2O)} = ?$

$m_{(H_2O)} = ?$

solution: $n = \dfrac{m}{M}$

$$n_{(H_2)} = \frac{1.00\times10^6\ \text{g}}{2.02\ \text{g/mol}}$$

$$= 4.9505\times10^5\ \text{mol}$$

$$n_{(H_2O)} = 4.9505\times10^5\ \text{mol}\ H_2 \times \frac{2\ \text{mol}\ H_{2(l)}}{2\ \text{mol}\ H_{2(g)}}$$

$$= 4.9505\times10^5\ \text{mol}$$

$$m_{(H_2O)} = 4.9505\times10^5\ \text{mol} \times 18.02\ \text{g/mol}$$

$$= 8.92\times10^6\ \text{g}\ \text{(3 significant digits)}$$

Textbook question 7: Some metals that form protective coatings when they corrode are tin, aluminum, chromium, and zinc.

Section 1: Follow-up Activities

Extra Help

1. a. $Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + e^-$ (oxidation)

   b. $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$ (reduction)

   c. $H_{2(g)} \rightarrow 2H^+_{(aq)} + 2e^-$ (oxidation)

   d. $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$ (oxidation)

2. The nail in test tube C will rust. Air and water are both necessary for rusting to occur. Both are present in test tube C. In test tube A the calcium chloride removes any moisture, while in test tube B the air was driven out of the water by boiling and kept out by the oil layer.

3. Air (oxygen) and water (moisture) are essential for the process of corrosion.

4. The additional factor that leads to extensive corrosion in the presence of an electrolyte.

5. Your chart should look as follows:

Method of Corrosion Prevention	Technique
coating	Coat the metal with paint, grease, or some other substance.
galvanization	Dip the object in molten zinc and then allow it to cool.
electroplating	Use electric current to deposit a fine layer of another metal on the object.
cathodic protection (sacrificial protection)	Attach a piece of a metal more reactive than the material the object is made of to the object.

Enrichment

1. The process of anodization involves making the layer of aluminum oxide thicker by electrolysis for more protection. The aluminum is used as the anode of a cell in which dilute sulphuric acid is electrolyzed. Oxygen gas forms at the anode and reacts with the aluminum. This allows for the layer of aluminum oxide to grow. Anodized aluminum is used for making window frames, saucepans, refrigerators, and so on.

2. Electroplating involves the use of electric current, whereas cladding involves a mechanical means of bonding another metal to the surface of the object. Electroplating is used in making silverware, trophies, tin cans, coins, and so on. An important use of cladding is in making window and door frames more weather-resistant. The following chart gives a comparison of the advantages and disadvantages of each method.

Protection Method	Advantages	Disadvantages
Electroplating	lasts longer	can be scratched off, particularly if layer is thin
Cladding	less expensive and easier to apply	may break off or separate

3. Many metals are useful when they are not pure. Iron is the most widely used metal and it is almost never used in pure form. It is too soft and rusts easily. The properties of any metal can be changed by mixing other metals with it. The mixture produced is called an alloy. When about 1% carbon is mixed with iron, it becomes much harder and stronger. It is called steel. When chromium and nickel are mixed with iron, it is called stainless steel, which is rust-resistant. In this form it can be used to make coins. Stainless steel is used for coins because it is more durable and less expensive than gold or silver coins.

Section 2: Activity 1

1. Electrochemical reaction is a reaction in which electrons are transferred between reacting species in a chemical reaction.

2. A spontaneous redox reaction can be used to produce an electric current.

3. a. The substance being oxidized **loses** electrons while the substance being reduced **gains** electrons.

   b. Electricity can be defined as **a flow of electrons**.

4. An electrochemical cell is also called a galvanic cell or a voltaic cell.

5. Each half-cell has an electrode and an electrolyte, which does not react with the electrode.

6. A salt bridge is a concentrated solution of an inert electrolyte. Its function is to prevent the buildup of excess positive charge in the cell. It also allows the flow of ions between the half-cells without letting the two electrolytes mix.

7. A cathode is the electrode in a cell where reduction takes place. The anode is the electrode where oxidation takes place.

8. It is essential to know if the reacting species will react spontaneously or not. A more reactive metal will displace a less reactive one. You can check this from the activity series.

9. Your observations chart may look something like the one that follows. Your voltage recorded for each may not be the same, but the order of the size of the voltage should be the same.

Cell	Voltage (V)	Colour/Mass Changes
Cu-Zn	1.10	Blue colour decreases in intensity. Zinc loses mass, copper is deposited on the copper electrode.
Cu-Mg	2.71	Blue colour decreases in intensity. Magnesium loses mass and copper is deposited at the copper electrode.
Zn-Mg	1.61	Magnesium loses mass and zinc is deposited at the zinc electrode.

10. **Textbook question 1:** The electrolytes are copper sulphate, zinc sulphate, and magnesium sulphate.

Textbook question 2: The electrodes are copper and zinc, copper and magnesium, and zinc and magnesium.

Textbook question 3: The flow of electrons between the two electrodes caused the voltmeter needle to move.

Textbook question 4: The copper-magnesium cell produced the highest voltage. They are the farthest apart in the activity series and have the maximum potential difference between them.

Textbook question 5: There is a spontaneous reaction which results in the zinc electrode giving up electrons. The electrons that it produces flow through the conducting wires to the copper ions in the other half-cell. The half-reaction for the process is $Zn_{(s)} \rightarrow Zn^{2+}{}_{(aq)} + 2e^-$. Zinc is being oxidized and forms the anode.

Textbook question 6: Copper ions pick up two electrons and change to solid copper. This solid gets deposited on the surface of the electrode. This electrode is the cathode. The half-reaction is $Cu^{2+}{}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$.

Textbook question 7: You will need to replace the zinc electrode and the copper sulphate solution.

Textbook question 8: The colour of the solution becomes less blue as copper ions change to copper atoms and are deposited on the zinc strip or settle at the bottom of the beaker.

11. The brown deposit that formed on the zinc is copper metal.

12. The blue colour faded because there are less copper ions in solution as these ions become copper metal.

13. The activity series tells you how the various metals relate to each in terms of how active they are and which metal will displace another metal when two metals are used in an electrochemical cell.

14. You have separate beakers so the solutions required for each half-cell do not mix.

15. The purpose of the salt bridge is to provide a path for ions to migrate to the opposite sides. This prevents like charges from collecting at opposite ends in the cell..

16. The zinc electrode is eroded as zinc metal is oxidized to zinc ions. The copper electrode builds up with copper as copper ions are reduced to copper metal.

17. Refer to the answers provided for Section 2, Activity 1, question 10.

18. Primary batteries cannot be recharged, whereas secondary batteries can be recharged.

19. Aluminum, lithium, and magnesium are the preferred choices of metal for the electrodes of lightweight batteries.

20. A major cause of car battery failure is corrosion of the collector or separation of the electrolyte from the collector's surface.

21. **Textbook question 1:** Your diagram should be similar to the one in Section 2, Activity 1 or the one on page 307 of *Visions 2*. The electrodes and electrolytes may not be the same as in these illustrations.

Textbook question 2:

Unit Analysis Method

Calculate the number of moles of $CuSO_{4(s)}$.

$$\text{molar mass} = 159.61\ \text{g/mol}\ CuSO_{4(aq)}$$

$$29.5\ \cancel{\text{g}\ CuSO_{4(s)}} \times \frac{1\ \text{mol}\ CuSO_{4(s)}}{159.61\ \cancel{\text{g}\ CuSO_{4(s)}}} = 0.184\ 83\ \text{mol}\ CuSO_{4(s)}$$

Calculate the concentration of $CuSO_{4(aq)}$.

$$0.184\ 83\ \text{mol}\ CuSO_{4(s)} \times \frac{1}{0.500\ \text{L}\ CuSO_{4(aq)}} = 0.370\ \text{mol/L}\ CuSO_{4(aq)}\ \text{(3 significant digits)}$$

Formula Method

data: $m_{(CuSO_4)} = 29.5\ \text{g}$

$M_{(CuSO_4)} = 159.61\ \text{g/mol}$

$V_{(CuSO_4)} = 500\ \text{mL}$

$n_{(CuSO_4)} = ?$

$C_{(CuSO_4)} = ?$

solution:

$$n = \frac{m}{M}$$

$$n_{(CuSO_4)} = \frac{29.5\ \text{g}}{159.61\ \text{g/mol}}$$

$$= 0.184\ 83\ \text{mol}$$

$$C = \frac{n}{V}$$

$$C_{(CuSO_4)} = \frac{0.184\ 83\ \text{mol}}{0.500\ \text{L}}$$

$$= 0.370\ \text{mol/L}\ \text{(3 significant digits)}$$

Textbook question 3: Water must be present as the electrolytes are aqueous solutions.

Textbook question 4(a): Oxidation will take place in the nickel half-cell. $Ni_{(s)} \rightarrow Ni^{2+}{}_{(aq)} + 2e^-$

Textbook question 4(b): Reduction will take place in the copper half-cell. $Cu^{2+}{}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

Section 2: Activity 2

1. An electrolytic cell uses electric current to force a non-spontaneous reaction to take place. A galvanic cell produces an electric current from a spontaneous redox reaction.

2. Your chart may look like the one that follows:

	Colour Change	Litmus Test
Electrode 1	yellow changed to dark brown	no change with either red or blue litmus
Electrode 2	none	red litmus turns blue blue litmus remains blue

3. The yellow colour of the potassium iodide solution changes to a dark brown colour, which indicates the presence of iodine. The half-reaction equation is $2I^-{}_{(aq)} \rightarrow I_{2_{(s)}} + 2e^-$. This electrode is the anode.

4. Reduction of water occurs at Electrode 2. You should see gas bubbling. This reaction produces hydrogen gas and hydroxide ions. The hydroxide ions change red litmus paper blue. This electrode is the cathode.

5. In the electrolysis of copper sulphate solution, reduction of copper ions will take place at the cathode. The reaction is as follows:

   $Cu^{2+}{}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

   Copper metal will be deposited on the electrode.

6. The reverse of a battery reaction is called electrolysis.

7. In the electrolytic cell the electrode connected to the negative end of the battery or power source acts as the **cathode**, and the electrode connected to the positive end acts as the **anode**.

8. There will be gas bubbles at one electrode and copper metal will be deposited on the other electrode.

9. The charge flow or electron flow is from the anode to the cathode.

10. A reduction reaction will occur at the negative (–) electrode. The half-reaction is $Cu^{2+}{}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$.

11. The reaction that occurs at the positive (+) electrode is the oxidation half-reaction.

12. The gas that bubbles at the anode is oxygen.

13. A power supply is needed to give electrical energy to the system so that a non-spontaneous reaction can take place.

14. Two purposes for electroplating are to make an object more attractive and to protect it from corrosion.

15. Silver, gold, chromium, copper, zinc, and nickel are metals that are frequently used for electroplating.

16. Answers will vary. Items can include inexpensive jewellery, trophies, toys, car accessories, and household appliances.

17. ABS plastic can be electroplated if it is first made to conduct electricity by etching its surface with a hot mixture of chromic acid and sulphuric acid.

18. The metal used for plating makes the anode in the electrolytic cell.

19. Very few cars have chrome parts today. The major reason for going away from the use of chromium is the high cost of this metal. Better paints make their use on corrosion-prone areas more acceptable today than in the past. Also, many corrosion-prone areas use plastic coatings or parts.

20. "Loonies" are punched out of nickel strips then electroplated with bronze, which is a mixture of 87.5% copper and 12.5% tin. An electric current is passed through a solution of potassium cyanide, potassium stannate and copper cyanide containing the nickel blanks. After a number of hours, the blanks are plated with a layer of bronze and sent to the Royal Canadian Mint for stamping.

21. The iron, zinc, and lead impurities would be oxidized and go into the solution since these metals are more reactive with acids, oxygen, and water. The gold and the platinum would settle out on the bottom since they are less reactive with acids, oxygen, and water than copper.

22. To be pure, a substance would have to have no atoms or molecules of any other substance. It is impossible through electrolysis to remove all traces of other substances.

23. Sodium metal and aluminum.

24. a. Find the number of kilograms in 1.9×10^{6} tonnes.

$$1.9\times10^{6}\times1.0\times10^{3}=1.9\times10^{9}\text{ kg}$$

Find the number of kilojoules of energy required.

$$1.9\times10^{9}\ \cancel{\text{kg}}\times\frac{8\times10^{5}\text{ kJ}}{10\ \cancel{\text{kg}}}=15\times10^{13}\text{ kJ}$$

$$=1.5\times10^{14}\text{ kJ}$$

Canada used about 1.5×10^{14} kJ of energy to produce primary aluminum in 1992.

b. $$\frac{1.5\times10^{14}}{1.8\times10^{15}}\times100=0.084\times100$$

$$=8.4\ \text{(2 significant digits)}$$

Of Canada's total electricity production in 1992, approximately 8.4% was used to produce primary aluminum.

25. **Textbook question 1:** Electrolysis is a process of producing a chemical change using an electric current. The two uses of electrolysis are electroplating and extraction of metals from their ores.

Textbook question 3: The anode of an electrolytic cell undergoes a decrease in mass, whereas the cathode increases in mass as time goes by. This principle can be applied to electroplate objects. The object to be plated is made to be the cathode and the plating metal is made to be the anode. The anode needs to be replaced after some time as it will oxidize and therefore undergo a mass loss.

Textbook question 4: From the equation on page 318, four moles of aluminum are produced from two moles of aluminum oxide. $2Al_2O_{3(l)} + 3C_{(s)} + \text{energy} \rightarrow 4Al_{(l)} + 3CO_{2(g)}$

Unit Analysis Method

Calculate the number of moles of $Al_2O_{3(l)}$.

$$\text{molar mass} = 101.96 \text{ g/mol } Al_2O_{3(l)}$$

$$956 \text{ g } Al_2O_{3(l)} \times \frac{1 \text{ mol}}{101.96 \text{ g } Al_2O_{3(l)}} = 9.3762 \text{ mol}$$

Calculate the number of moles of $Al_{(s)}$.

$$9.3762 \text{ mol } Al_2O_{3(l)} \times \frac{4 \text{ mol } Al_{(s)}}{2 \text{ mol } Al_2O_{3(l)}} = 18.752 \text{ mol } Al_{(s)}$$

Calculate the mass of $Al_{(s)}$.

$$\text{molar mass} = 26.98 \text{ g/mol } Al_{(s)}$$

$$18.752 \text{ mol } Al_{(s)} \times \frac{26.98 \text{ g } Al_{(s)}}{1 \text{ mol } Al_{(s)}} = 506 \text{ g } Al_{(s)} \text{ (3 significant digits)}$$

Formula Method

data:

$$m_{(Al_2O_3)} = 956 \text{ g}$$
$$M_{(Al_2O_3)} = 101.96 \text{ g/mol}$$
$$M_{(Al)} = 26.98 \text{ g/mol}$$
$$n_{(Al_2O_3)} = ?$$
$$n_{(Al)} = ?$$
$$m_{(Al)} = ?$$

solution:

$$n = \frac{m}{M}$$
$$n_{(Al_2O_3)} = \frac{956 \text{ g}}{101.96 \text{ g/mol}}$$
$$= 9.3762 \text{ mol}$$

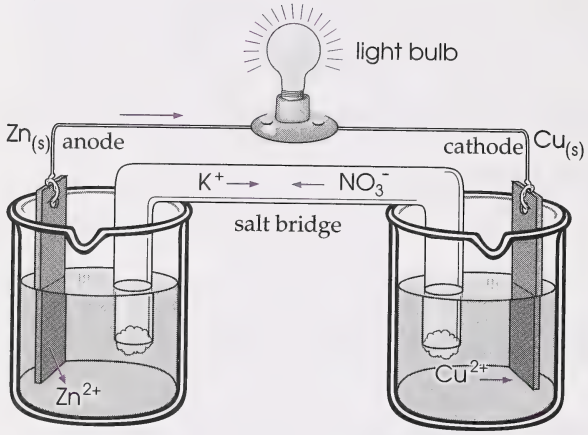
$$n_{(Al)} = 9.3762 \text{ mol} \times \frac{4 \text{ mol } Al_{(l)}}{2 \text{ mol } Al_2O_{3(l)}}$$
$$= 18.752 \text{ mol}$$

$$m = nM$$
$$m_{(Al)} = 18.752 \text{ mol} \times 26.98 \text{ g/mol}$$
$$= 506 \text{ g (3 significant digits)}$$

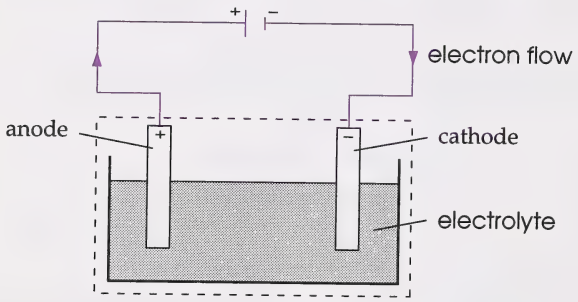
Section 2: Follow-up Activities

Extra Help

1. This is an electrochemical cell.



2. This is an electrolytic cell because the diagram shows that a power supply is used to drive the reaction.



3. Your completed chart should look like the following:

	Galvanic Cell	Electrolytic Cell
Type of Reaction	spontaneous	non-spontaneous
Energy Changes	chemical to electrical	electrical to chemical
Anode Reaction	oxidation	oxidation
Cathode Reaction	reduction	reduction
Electron Flow	anode to cathode	anode to cathode

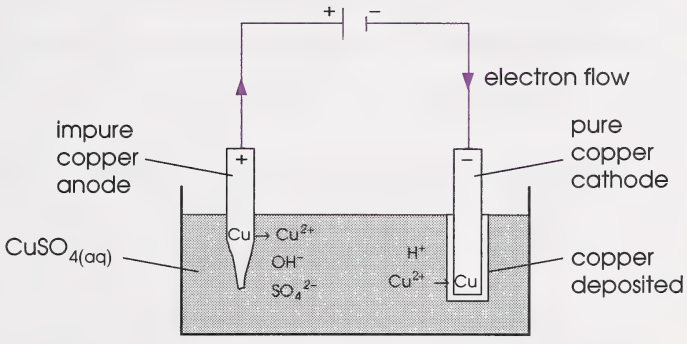
4. Galvanic cells are used as batteries, and electrolytic cells are used for electroplating or metal extraction.

5. a. The chromium half-reaction will occur at the anode, and the lead half-reaction will occur at the cathode.

   b. The chromium is oxidized and the lead is reduced.

Enrichment

1. The following is an example. You may have used a different metal to illustrate the process in your answer. In electrorefining, a pure metal is deposited on the cathode of an electrolytic cell from an impure anode. Refining of copper is important, as copper is used in making electric wires and must be very pure. A little impurity will reduce its electrical conductivity a lot. An aqueous solution of copper(II) sulphate is electrolysed. A block of impure copper is used as an anode and pure copper is used as the cathode. Refer to the diagram.



2. An ion is more readily oxidized if it is present in higher concentrations. For example, when a solution containing 1 mol/L of OH^- ions and Cl^- ions is electrolyzed, OH^- ions are discharged. But when 3 mol/L NaCl solution undergoes electrolysis, Cl^- ions are oxidized because their concentration is much greater than that of OH^- ions. Similarly, when equilibrium is reached, the tendency for the reaction to go in the forward direction and the reverse direction is the same. This is because the concentrations of the ions have changed. The voltage produced changes as well. Actually the voltage for a reaction that has reached equilibrium is zero.

3. Half-cell overpotential is the difference between the actual potential required and the calculated potential required for the electrolytic cell. The reason why this difference exists is because of the temperature changes, the current density, the type of electrode used, and the time factor involved.

Section 3: Activity 1

1. A hydrocarbon is a compound containing carbon and hydrogen.

2. Oil, coal, and natural gas are three primary sources of hydrocarbons.

3. The sources of hydrocarbons and organic compounds are the same because the hydrocarbons are a part of the large group called organic compounds.

4. A fossil fuel is a hydrocarbon formed from dead plants and animals millions of years ago. Some examples are coal, natural gas, and oil.

5. A and C are hydrocarbons. These two compounds contain only hydrogen and carbon atoms.

6. Because carbon has four valence electrons, it has four bonding sites.

7. There are six bonding sites left on the two carbon atoms.

8. Answers will vary. The colour of the flame with the air hole closed will be yellow. You should have noticed droplets of water build up on the outside of the test tube. There may be some soot deposited on the test tube when the air hole is closed. With the air hole open, the flame will be blue in colour. The test tube held over the candle flame will show droplets of water as well as a buildup of black soot.

9. **Textbook question 1:** The equation for combustion of methane is as follows:

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

When the hole is closed, the air supply is decreased. As a result, incomplete combustion occurs, producing soot and a yellow colour flame.

Textbook question 2: The combustion equation for paraffin wax is as follows:

$$C_{25}H_{52(s)} + 38O_{2(g)} \rightarrow 25CO_{2(g)} + 26H_2O_{(g)}$$

10. You will see water droplets on the test tube as well as a buildup of black soot.

11. Refer to the answer provided for Section 3, Activity 1, question 9.

12. In a complete hydrocarbon combustion reaction, the products are carbon dioxide gas and water vapour.

13. They are both C_4H_{10}.

14. They differ in the arrangement of their atoms.

15. No, the two hydrocarbons will not have the same properties. The arrangement of their atoms will determine their chemical and physical characteristics. Since their atoms are arranged differently, their properties will also be different.

16. The condensed formula would be $CH_2 = CH - CH_3$. Notice how the hydrogen atoms that are bonded to the carbon atoms are grouped with the carbon atom. The condensed formula written as $CH_2 = CHCH_3$ is acceptable as well.

17. The molecular formula for each isomer is C_5H_{12}. The condensed formulas are as follows.

a. $CH_3 - CH_2 - CH_2 - CH_2 - CH_3$

b. $CH_3 - CH(CH_3) - CH_2 - CH_3$

c. $CH_3 - C(CH_3)_2 - CH_3$

18. The minimum number of carbon atoms needed is four. With only three carbons, the branches cannot go anywhere except on the end, so they are not considered to be branches.

19. As the number of carbon atoms increases, so does the number of isomers.

20. The condensed structural formulas are as follows:

a. $CH_3-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

c. $CH_3-CH_2-CH=CH_2$

b. $CH\equiv C-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

Section 3: Activity 2

1. One pattern that emerges is that the melting and boiling points increase as the number of carbon atoms increase. Also, the molecular formulas of two adjacent alkanes differ by a $-CH_2-$ unit.

2. Homologous series means that it is a family of compounds all having the same general formula, with members differing from the next by a $-CH_2-$ unit.

3. The general formula for alkanes is C_nH_{2n+2}.

4. The prefixes used are pent-, hept-, and non-, respectively.

5. a. $C_{11}H_{24}$

   b. $C_{24}H_{50}$

   c. $C_{31}H_{64}$

   d. $C_{54}H_{110}$

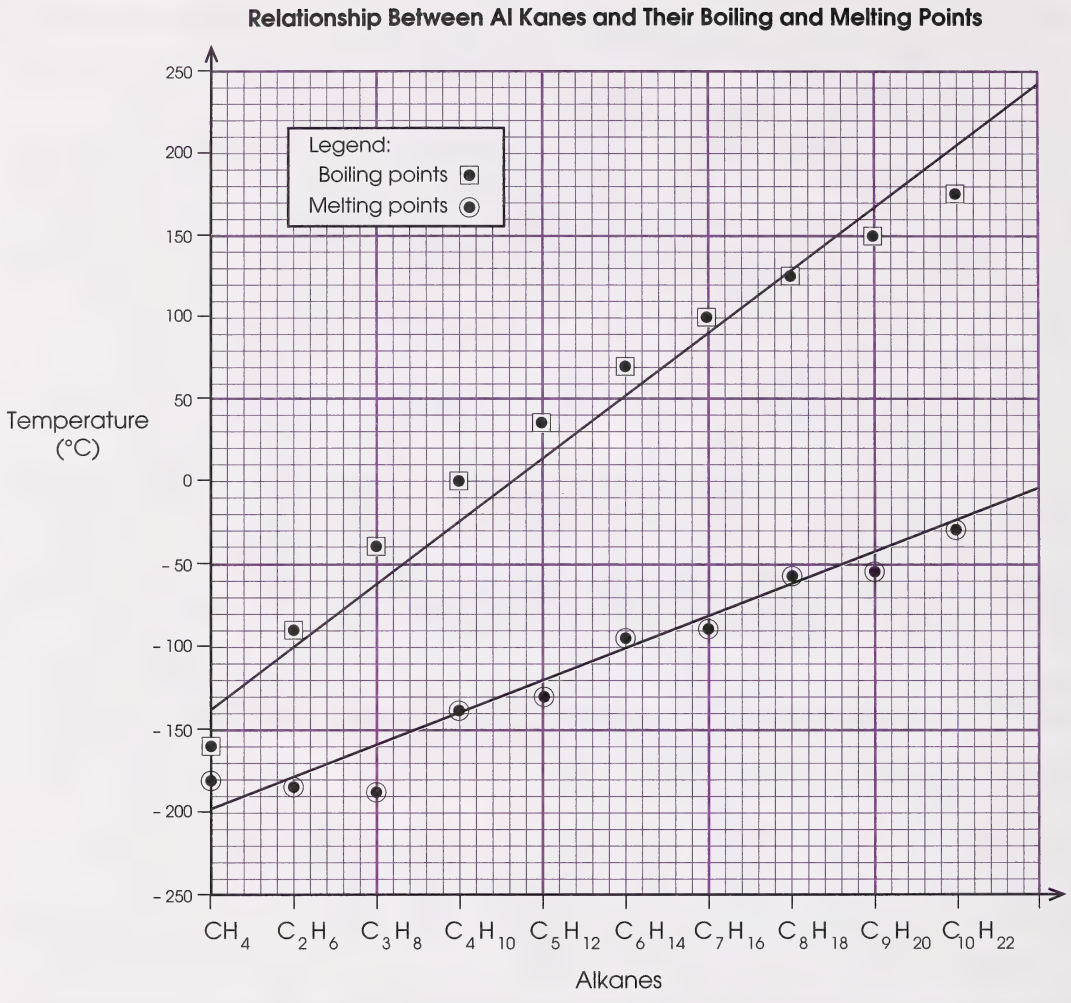
6. **Textbook question 1:** Methane to butane are gases, and pentane to decane are liquids at room termperature.

   Textbook question 2: Decane has the highest boiling point and the highest molar mass.

   Textbook question 3: Methane has the lowest boiling point and the lowest molar mass.

   Textbook question 4: Methane has the lowest melting point, but decane will freeze first.

   Textbook question 5: As the molar mass increases, both the melting point and the boiling point also increase. The graph is as follows:



7. a. This is a chain of three carbons; thus, you use the prefix *prop-*. There are only single bonds, so the suffix is *-ane*. Therefore, the name for $CH_3 - CH_2 - CH_3$ is propane.

   b. This is a chain of seven carbons so you use the prefix *hept-*. There are only single bonds, so the suffix is *-ane*. Therefore, the name for $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$ is heptane.

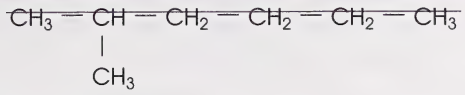
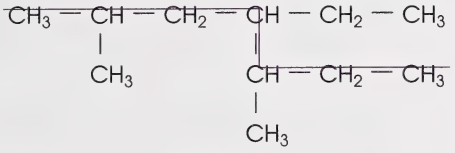
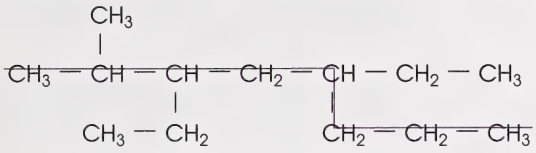
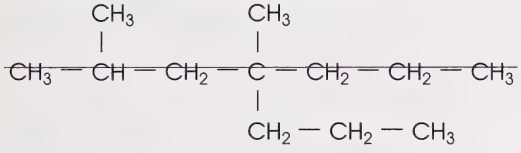
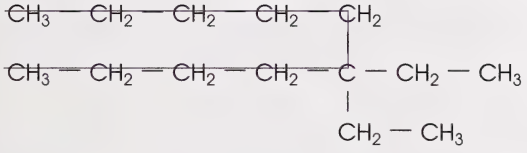
8. a. A branch is a carbon chain that is attached to the main chain of a hydrocarbon compound.

   b. The branch name has a *-yl* ending to distinguish it as a branch.

   c. All alkane compounds have names ending in *-ane*.

9. The parent chain is numbered from the end that gives the branches the lowest possible locating numbers.

10.

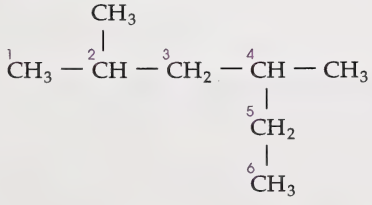
Structural Diagram	Name of Parent Chain
	hexane
	heptane
	octane
	heptane
	decane

11. The names are as follows:

a. butane b. 2,2-dimethylpropane c. 2-methylbutane d. 3-ethyloctane

Note: The answer for 11b. may also be called dimethylpropane since there is no place else the methyl groups can be.

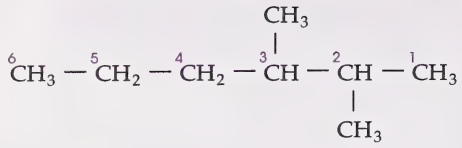
12. a.



The name does not reflect the longest continuous chain. The correct name should be 2,4-dimethylhexane.

~~4-ethyl-2-methylpentane~~

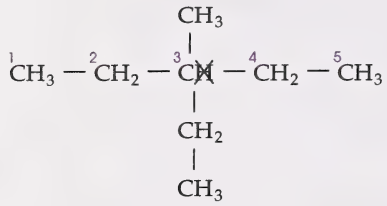
b.



~~4,5-methylhexane~~

The main chain was numbered from the wrong end. Therefore, the name is wrong. The *di-* prefix in front of methyl is also missing. The correct name should be 2,3-dimethylhexane.

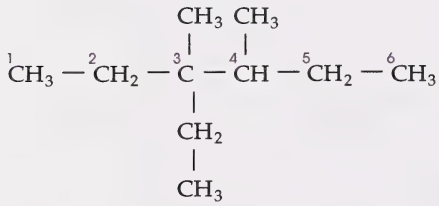
c.



~~3-methyl-3-ethylpentane~~

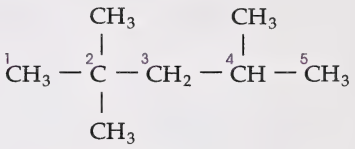
Carbon number 3 has too many bonds – the H should be removed. The branch names are not in alphabetical order. The correct name should be 3-ethyl-3-methylpentane.

13. a. 3-ethyl-3,4-dimethylhexane



Note: Other configurations are possible.

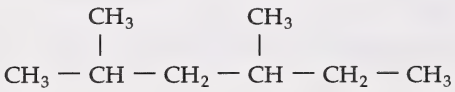
b. 2,2,4-trimethylpentane



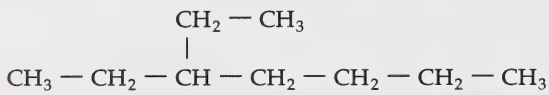
14. **Textbook question 1(b):** 3-ethylpentane

Textbook question 1(c): 2,4-dimethylhexane (Note: Count the longest chain.)

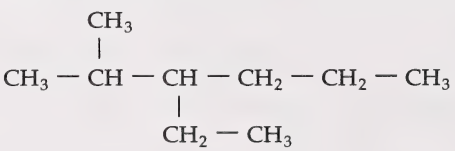
Textbook question 2(a):



Textbook question 2(b):



Textbook question 2(c):



15. The advantages are that they are non-toxic and they may be used in the manufacture of plastics, agricultural chemicals, and pharmaceuticals.

16. A major problem is that they adversely affect the environment. Plastics are not biodegradable, and some of these chemicals affect Earth's upper atmosphere.

17. Industry and government agencies are trying to eliminate the use of CFC's. The use of CFC's has been eliminated in aerosol cans. They are still used as refrigeration coolants but industry is looking for other chemicals which will work as well but not harm the environment.

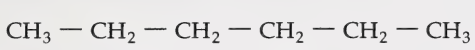
18. This process is used to manufacture alkenes needed for the polymer industry and to change heavier products of distillation to lighter fractions for gasoline.

19. Catalytic reforming changes straight-chain hydrocarbons into branched-chain and ring hydrocarbons. In catalytic cracking, long-chain hydrocarbons are separated into shorter chain molecules.

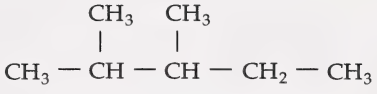
20. **Textbook question 1:** There are more organic compounds because of the nature of the carbon atom. It has four bonding sites and forms covalent bonds. It also has the ability to form long chains of molecules by linking itself to other carbon atoms. Each of these chains is a different organic compound.

    Textbook question 2: Fractional distillation is a process in which different fractions of oil are separated by heating the oil in a fractionating tower. In cracking, the oil is heated in the absence of air and the molecules break down to form smaller chain molecules. In reforming, straight-chained hydrocarbons are broken into smaller molecules which then join to form branched compounds.

    Textbook question 3: Answers may vary.



hexane (continuous chain)



2,3-dimethylpentane (branched)

    Textbook question 4(a): pentane

    Textbook question 4(b): 2-methylhexane

    Textbook question 4(c): 2,3-dimethylbutane

    Textbook question 4(d): 3-methylpentane

Section 3: Activity 3

1. a. The major use of ethene is in the production of plastic packaging, plastic cups, insulation, antifreeze, detergents, and so on.

   b. Answers will vary but should include products such as plastic bags (bread bags, freezer bags), plastic cups, plastic food containers, polystyrene, detergents, antifreeze, and so on.

2. Alberta has large quantities of natural gas which is high in ethane content used to produce ethene.

3. The general formula is C_nH_{2n}.

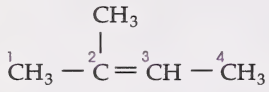
4. Alkenes have two less hydrogen atoms than alkanes.

5. The name of the first member is ethene. Its common name is ethylene. Its condensed structural formula is $CH_2 = CH_2$.

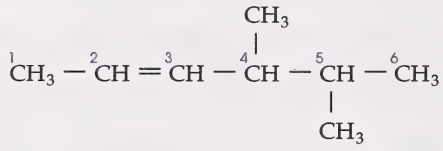
6. **Textbook question 1(a):** 3,6-dimethyl-3-octene

   Textbook question 1(b): 5-ethyl-2-heptene

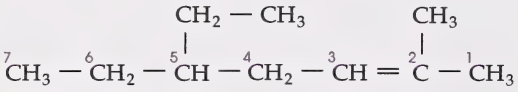
   Textbook question 2(a):



   Textbook question 2(b):



   Textbook question 2(c):



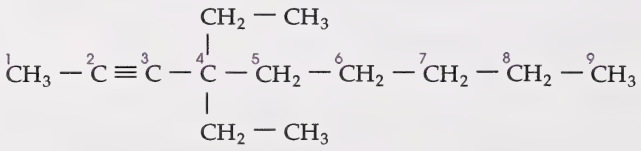
7. Alkynes have two less hydrogens than alkenes, and four less hydrogens than alkanes.

8. The names of the compounds are as follows:

   a. 4-methyl-1-pentyne b. 2,2,5-trimethyl-3-heptyne

9. **Textbook question 1(a):** 2-methyl-3-hexyne

   Textbook question 2(a):



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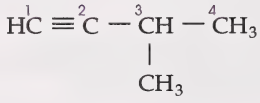
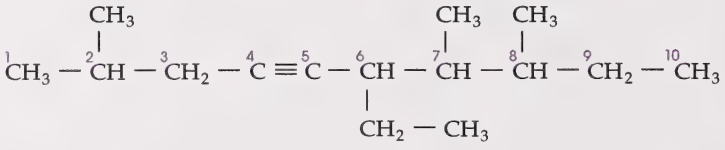


   Textbook question 2(c):



10. React the substances with bromine in the dark. If the red-orange colour of bromine disappears, it indicates that a reaction has occurred and the substance must be an unsaturated compound. If no reaction occurs (colour remains), then the substance must be an alkane.

11. The addition of a water molecule to an alkene produces an alcohol.

12. The formula is $HOCH_2CH_2OH$. Ethylene glycol is used as an antifreeze for motor vehicles.

13. Hydrogenation is the addition of hydrogen molecules to unsaturated hydrocarbons. This process is used in the food industry to change unsaturated liquid oils into solid saturated fats.

14. **Textbook question 2:** Alkanes are less reactive compared to alkenes. This can be seen in the reaction with bromine where alkanes require the energy from sunlight for the reaction to proceed while alkenes do not. Both alkanes and alkenes undergo combustion reactions; but alkenes undergo addition reactions, whereas alkanes undergo substitution reactions.

    Textbook question 3: Saturated means all bonds between the carbon atoms are single bonds, whereas unsaturated means that there may be double or triple bonds between carbon atoms. Since alkenes and alkynes have double and triple bonds, they are unsaturated hydrocarbons.

    Textbook question 4(a): $CH_2 = CH_{2(g)} + H_{2(g)} \xrightarrow{Pd} CH_3 - CH_{3(g)}$

    Note: Pd is palladium. This reaction is done with palladium as a catalyst.

    Textbook question 4(b): $CH_3 - CH_2 - CH = CH_{2(g)} + Br_{2(l)} \rightarrow CH_3 - CH_2 - CHBr - CH_2Br_{(l)}$

Section 3: Activity 4

1. Other natural polymers include rubber, complex carbohydrates, proteins, and nucleic acids. Rubber is produced by the rubber plant, and carbohydrates are synthesized by plants as well. Proteins and nucleic acids are the building blocks of animals.

2. The amino group (NH_2) and a carboxyl group (COOH) make up an amino acid.

3. The different functions of proteins are determined by the type of amino acid and the order in which they link up.

4. Complex carbohydrates are made up of glucose.

5. Answers may vary. A number of useful properties of plastics are as follows.

    - easy to mold
    - do not corrode
    - lightweight
    - smooth
    - strong
    - insulator
    - inexpensive to produce
    - flexible or rigid

6. There was a need to replace natural substances which were becoming scarce and expensive. This resulted in the search for various materials to replace these substances. While looking for specific substances, chemists came up with a long list of new materials.

7. Answers may vary. Examples of thermoplastics include the following:

   - polyethene
   - polyvinylchloride (PVC)
   - nylon
   - terylene
   - polystyrene
   - glass

8. Thermoplastics melt or soften when heated; therefore, they are not used to make saucepan handles.

9. Thermosets are not flexible like plastics. They are harder, stronger, and more resistant to heat than plastics.

10. Thermosets are plastics which cannot be softened again by heat once they are set hard. This is because cross-links are formed between chains at various points when thermosets are heated to mould and shape the first time. This results in a hard, rigid structure. Refer to the diagrams on page 355 of *Visions* 2.

11. Answers will vary. Examples of materials produced by condensation reactions include nylon (carpets, ropes), polyesters (ropes), and polycarbonates (bullet proof windows). An example of a material produced by an addition reaction is polyethene.

12. The oil and gas industry presently provides most of the monomers for the production of plastics.

13. The purpose of this investigation is to distinguish between various types of common plastic materials.

14. Your observations chart should look like the following:

Substance	Rigidity	Floats in Water	Marks with HB Pencil	Heat
polyethylene	not rigid	yes	yes	melts
polypropylene	not rigid	yes	yes	burns with green flame on copper wire
cellulose acetate	spongy	no	no	smoke smells like vinegar
polystyrene	spongy	yes	yes	no green colour with copper; no ash on heating
nylon	spongy	no	no	no smoke; ash left
acrylic	rigid	no	no	no smoke; no ash

15. **Textbook question 1:** Polyethylene, polypropylene, and polystyrene are thermoplastics; the rest of the substance listed in the chart are thermosets.

Textbook question 2: Any black substance that forms is likely soot. Soot forms when the combustion of carbon is incomplete.

Textbook question 3: Cellulose acetate is produced by treatment of cellulose with ethanoic acid. The acetate forms acetic acid (vinegar) when combined with hydrogen.

Textbook question 4: The chlorine burns with a green colour. Chlorine also combines with copper to make it more volatile.

16. Answers will vary. University graduate careers include the following:

- polymer chemists (organic chemists) – involved in research, development, and testing of new materials and products
- chemical engineers – design equipment and processes required to manufacture new materials and products
- mechanical engineers – design equipment required to produce new materials

Technical school graduate careers include the following:

- chemical technologists – work with designers and engineers in the development of new products
- plastics technologists – design moulds required to produce new products as well as operate machinery required to produce new products
- plastics mould drafters – design plans and blueprints for various machine moulds for new products

Note: Go to page 357 of *Visions 2* for other careers in the plastics industry.

17. Answers will vary. Your essay should include what career you have chosen, what is involved in this career, and why you would be interested in this career. You might also include ideas on career advancement and opportunities to work in various cities or countries in your essay.

18. **Textbook question 1:**

	Polymers	Uses
Natural	proteins	building blocks of living cells
	carbohydrates	energy source for living systems
	DNA	genetic material in living systems
Synthetic	polythene	plastic bags, plastic dustbins
	polystyrene	packaging material, plastic cups
	nylon	ropes, clothing

Synthetic polymers are made by humans while natural polymers are found in living materials.

Textbook question 2: Thermoplastics can be heated and softened and remoulded. Thermosets can be heated only once and moulded to a given shape.

Textbook question 3: Some different uses for plastics include the following:

- dishes
- toys
- machinery parts
- clothing
- containers
- tools
- food wrap
- building materials

Section 3: Follow-up Activities

Extra Help

1. a. true
   b. false
   c. true
   d. true
   e. true

2. C_2H_4 and C_4H_{10} are hydrocarbons.

3. a. C_5H_{12}: $CH_3 - CH_2 - CH_2 - CH_2 - CH_3$

   b. C_4H_8: $CH_2 = CH - CH_2 - CH_3$

   c. C_2H_2: $CH \equiv CH$

   d. C_4H_{10}:
   $$\begin{array}{l} CH_3 - CH - CH_3 \\ \qquad\quad | \\ \qquad\quad CH_3 \end{array}$$

   e. C_8H_{16}:
   $$\begin{array}{l} CH_3 - CH - CH = CH - CH_2 - CH_2 - CH_3 \\ \qquad\quad | \\ \qquad\quad CH_3 \end{array}$$

4. The general formulas for alkanes, alkenes, and alkynes are C_nH_{2n+2}, C_nH_{2n}, and C_nH_{2n-2} respectively.

5. a. 2-pentene
   b. propyne
   c. 2-methylhexane
   d. propene
   e. 4-methyl-1-hexene
   f. 2,3-dimethylpentane

   Note: The bond location number for 5b. and 5d. (1-propyne and 1-propene) does not have to be inserted because the number is always the same no matter where the location of the double or triple bond is. However, 1-propyne and 1-propene are correct answers as well.

6. The isomers are represented by A and B.

7. In an addition reaction, a molecule is added to an alkene and becomes part of the molecule. In a substitution reaction, a hydrogen atom is removed and its place is taken by a new atom.

8. A monomer is a single unit which is repeated several times in a polymer. A monomer is a simple molecule, and a polymer is a large complex molecule made up of repeating units of the simple molecule.

Enrichment

1. Some of the ways to deal with this problem are as follows:

   - Recycle plastic. Thermoplastic waste can be recycled, but is not very economical because pigments are still present in the plastic.
   - They can be used as fuel, but this causes pollution problems.
   - There are some biodegradable plastics. Their use should be promoted.

2. When low-grade coal is burned, fumes of sulphur dioxide gas are given off. This reacts with the oxygen in air to form sulphur trioxide gas $\left(SO_{3(g)}\right)$. This gas dissolves in water to form sulphuric acid. This comes down as acid rain and destroys Earth's natural habitat.

   - $S_{8(s)} + 8O_{2(g)} \rightarrow 8SO_{2(g)}$
   - $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$
   - $SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$

3. Answers will vary. You may need to research newspaper and magazine articles. You need to include arguments for and against each approach; then take one side and justify your answer.

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Science 20

Student Module Booklet

Module 6

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